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Alpena MI

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Remedial Investigation Report of Sites 1-9 at Alpens CRTC, Alpena MI. Volume II Sections 4-6.
A remedial investigation was performed on 9 sites at the Alpena CRTC to determine the extent of contamination at the sites. The sites involved in this investigation include: Site 1 POL Storage Area; Site 2 Motor Pool Area; Site 3 Former Garage; Site 4 Third Fire Training Area; Site 5 Second Fire Training Area; Site 6 Former Landfill; Site 7 First Fire Training Area; Site 8 Former Hanger 9; Site 10 Hazardous Waste Storage Area. Soil and groundwater contamination above state action levels was found at the sites. An FS has been initiated.

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INSTALLATION RESTORATION PROGRAM

FINAL
REMEDIAL INVESTIGATION REPORT

VOLUME II: SECTIONS 4 - 6

ALPENA COMBAT READINESS TRAINING CENTER
ALPENA COUNTY REGIONAL AIRPORT, MICHIGAN AIR NATIONAL GUARD
ALPENA, MICHIGAN

JUNE 1995

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HAZARDOUS WASTE REMEDIAL ACTIONS PROGRAM
Environmental Restoration and Waste Management Programs
Oak Ridge, Tennessee 37831-7606
managed by MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the U.S. DEPARTMENT OF ENERGY under contract DE-AC05-84OR21400

FINAL

INSTALLATION RESTORATION PROGRAM
REMEDIAL INVESTIGATION REPORT

ALPENA COMBAT READINESS TRAINING CENTER,
ALPENA COUNTY REGIONAL AIRPORT
MICHIGAN AIR NATIONAL GUARD
ALPENA, MICHIGAN

Submitted to:

AIR NATIONAL GUARD READINESS CENTER
ANDREWS AFB, MARYLAND

Submitted by:

HAZARDOUS WASTE REMEDIAL ACTIONS PROGRAM
MARTIN MARIETTA ENERGY SYSTEMS, INC.
Oak Ridge, Tennessee 37831

For:

U.S. DEPARTMENT OF ENERGY

Prepared by:

EARTH TECH
Oak Ridge, Tennessee 37830

JUNE 1995

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TABLE OF CONTENTS

REMEDIAL INVESTIGATION REPORT
ALPENA COMBAT READINESS TRAINING CENTER
MICHIGAN AIR NATIONAL GUARD
ALPENA, MICHGIAN

Volume II

Figures

Tables

ACRONYMS AND ABBREVIATIONS

AGE	Aerospace Ground Equipment
AMS	Arts Manufacturing and Supply
ANG	Air National Guard
ANGRC	Air National Guard Readiness Center
ARARs	Applicable or Relevant and Appropriate Requirements
ASTM	American Society for Testing and Materials
B(a)a	benzo(a)anthracene
B(a)p	benzo(a)pyrene
B(b)f	benzo(b)fluoranthene
BCE	Base Civil Engineer
BEHP	Bis (2-ethylhexyl) Phthalate
bgs	below ground surface
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
C	Celsius
CCl_4	Carbon Tetrachloride
CDI	Chronic Daily Intake
CE	Civil Engineering
CEC	Cation Exchange Capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Chy	Chrysene
CLP	Contract Lab Program
cm/day	centimeters per day
cm	centimeter(s)
cm/s	centimeters per second
COPC	Chemical of Potential Concern
Cr(III)	Chromium trivalent form
Cr(VI)	Chromium Hexavalent form
$Cr(OH)_3$	Isoluble chromium hydioxide
CRAVE	Carcinogen Risk Assessment Verification Endeavor
CRDL	Contract Required Detection Limits
CRQL	Contract Required Quantitation Limits
CRTC	Combat Readiness Training Center
DBF	dibenzofuran
DCA	Dichloroethane
DCB	Dichlorobenzene
DCE	Dichloroethylene
DD	Decision Document

DL	Detection Limits
DOD	U.S. Department of Defense
DQO	Data Quality Objective
ECD	Electron Capture Detector
EMI	Electromagnetic Induction
EPA	U.S. Environmental Protection Agency
ER	Equipment Rinseates
ES	Executive Summary or Engineering-Science
F	Fahrenheit
FASP	Field Analytical Support Project
FB	Field Blanks
FG	Fighter Group
FID	Flame Ionization Detector
FS	Feasibility Study
FSP	Field Sampling Plan
ft/day	feet per day
ft	foot/feet
ft/ft	foot (feet) per foot
ft^2/day	square feet per day
ft^2	square feet
FTA	Fire Training Area
g	gram
g/m^3	gram per cubi meter
g/ml	gram per mililiter
gm/kg	gram per kilogram
gal	gallon(s)
GC/MS	Gas Chromatography/Mass Spectrometry
GC	Gas Chromatograph
gpd	gallons per day
gpm	gallon(s) per minute
GSI	Groundwater-Surface Water Interface
ha	hectare(s)
HAZWRAP	Hazardous Waste Remedial Actions Program
HEAST	Health Effects Assessment Summary Tables
HI	Hazard Index
HMTC	Hazardous Materials Training Center
HQ	Hazard Quotient

I(1,2,3)	Indeno(1,2,3,c-d)pyrene
IARC	Internal Agency for Research on Cancer
ID	Inner Diameter
IRP	Installation Restoration Program
JP-4	Petroleum Jet Fuel #4
K	Hydraulic Conductivity
km	kilometer(s)
ℓ	liter(s)
ℓpm	liter(s) per minute
LCS	Laboratory Control Sample
LOAEL	Lowest Observed Adverse Effect Level
LQL	Lower Quantifiable Limit
µg/g	microgram(s) per gram
µg/ℓ	microgram(s) per liter
µg/kg	microgram(s) per kilogram
µg/m^3	microgram(s) per meter
µm	micrometer
m/m	meter(s) per meter
m	meter(s)
m^2	square meter(s)
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
MDNR	Michigan Department of Natural Resources
MERA	Michigan Environmental Response Act
MF	Modifying Factor
mg/kg	milligram(s) per kilogram
mg/ℓ	milligram(s) per liter
mg/m^3	milligram(s) per meter
mi	mile(s)
MIANG	Michigan Air National Guard
ml	milliliter(s)
mm	millimeter(s)
MOC	Method of Characteristics
MOGAS	motorgasoline
MS/MSD	Matrix Spike/Matrix Spike Duplicate
msl	Mean Sea Level
MTBE	Methyl Tertiary Butyl Ether

NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observed Adverse Effect Level
NPDES	National Pollution Discharge Elimination System
OD	Outside Diameter
oz	ounce(s)
PA	Preliminary Assessment
PAH	Polynuclear Aromatic Hydrocarbons
PARCC	Precision, Accuracy, Representativeness, Comparability, and Completeness
PCA	Tetrachloroethane
PCB	Polychlorinated Biphenyl
PCE	Tetrachloroethene or Tetrachloroethylene
PD-680	Petroleum Distillate 680
Phen	Phenanthrene
PID	Photo Ionization Detector
POL	Petroleum, Oil, and Lubricants
ppb	part(s) per billion
ppm	part(s) per million
PPM	Priority Pollutant Metals
PRE	Preliminary Risk Evaluation
PS-661	Petroleum Solvent 661
PVC	Polyvinyl Chloride
QA	Quality Assurance
QA\QC	Quality Assurance\Quality Control
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RF	Response Factor
RfD	Reference Dose
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
RPD	Relative Percent Difference
SAP	Sampling and Analysis Plan
Sci-Tek	Science and Technology
SF	Slope Factors
SI	Site Investigation
SOP	Standard Operating Procedure
SOV	Soil Organic Vapor
SOW	Statement of Work

SQL	Sample Quantitation Limit
SRAP	Source Removal Action Plan
SVOC	Semivolatile Organic Compound
T	Transmissivity Values
TAL	Target Analyte List
TB	Trip Blanks
TBD	To Be Determined
TCA	Trichloroethane
TCE	Trichloroethene or Trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
TPH	Total Petroleum Hydrocarbons
TVOC	Total Volatile Organic Compound
UCL	Upper Confidence Limit
UF	Uncertainty Factor
USCS	Unified Soil Classification System
UST	Underground Storage Tank
VOC	Volatile Organic Compound
WP	Work Plan
yd	yard(s)

4.0 BASELINE RISK ASSESSMENT

The following sections discuss baseline risks associated with human health and the environment for the following sites:

Site 1	POL Storage Area
Site 2	Motor Pool Area
Site 3	Former Site of County Garage
Site 4	Third Fire Training Area
Site 5	Second Fire Training Area
Site 6 & 7	Former Solid Waste Landfill and First Fire Training Area
Site 8	Former Site of Hangar 9
Site 9	Radar Tower Site.

The data from each site was first evaluated under Michigan Environmental Response Act (Act 307 of 1982) to determine initial chemicals of potential concern. This Act and its application to the sites at Alpena CRTC is described in Section 4.1. Section 4.2 describes the rationale used to develop the final data set for use in the human health risk assessment. Sections 4.3 through 4.5 describe the methodology used to assess exposure, toxicity, and risk. Section 4.6 presents non-site specific data regarding physical and chemical properties and fate and transport for chemicals of concern found at the nine sites. Sections 4.7 through 4.14 present the human health risk assessment for Sites 1 through 9. The environmental assessment is presented in Section 4.15.

4.1 MICHIGAN ENVIRONMENTAL RESPONSE ACT 307

The Michigan Environmental Response Act (Act 307 of 1982) provides for the identification, risk assessment, and priority evaluation of environmental contamination sites in the State of Michigan. Act 307 identifies three types of cleanup criteria:

Type A - Background (or method detection limit)
Type B - Risk-based with standardized exposure assumptions
Type C - Risk-based with site specific exposure assumptions.

Type B criteria and Type A (where appropriate) have been used for evaluation of the sites at Alpena CRTC. These criteria are presented in Table 4-1. A discussion of the three clean-up types follows.

Table 4-1 Michigan Act 307 Type A and B Criteria
MIANG, Alpena CRTC, Alpena, Michigan

	Groundwater Criteria			Soil Criteria		
Chemical	Type A Local Background Mean Value (ppb; dissolved metals)	Type B Health Based Drinking Water Value (ppb)	GSI Value (ppb)	Type B 20X Drinking Water Value (ppb)	Direct Contact Value (ppb)	Type A Default Value (ppb)
Acenaphthene		1200	{D}	24000	4.5E+7	
Acenaphthylen		25	{D}	500	9.3E+5	
Acetone		700	500	14000	7.8E+6	
Acetonitrile		130	810	2600	1.5E+6	
Acrolein		110	2.5	2200	1.2E+6	
Acrylamide		0.0077	9.1	0.15	280	
Acrylic acid		580	{D}	12000	6.4E+6	
Acrylonitrile		0.063	2.2	1.3	700	
Alachlor		0.42	{D}	8.4	16000	
Aldrin		0.0021	0.0014{Q}	{G}	76	
Aluminum		ID;50{H}{R}	{D}	1000{C}	ID	6900000
Aniline		6.3	4	130	2.3E+5	
Anthracene		7000	1.1E+5{Q}	1.4E+5	2.6E+8	
Antimony	16.90	2.4{C}	4300{C,Q}	48{C}	91000	
Arsenic	1.85	0.02{C}	1.4{C,Q}	8.4{C}	720{C}	5800
Atrazine		0.16	{D}	3.2	5800	
Azobenzene		0.32	{D}	6.4	12000	
Barium		2400{C}	630{C}	48000{C}	1.8E+7	75000
Benzene		1.2	60	24	13000	
Benzidine		0.00015	0.0054{Q}	0.003	5.6	
Benzo(a)anthracene		0.0049	0.31{Q}	{G}	180	
Benzo(a)pyrene		0.0049	0.31{Q}	{G}	180	
Benzo(b)fluoranthene		0.0049	0.31{Q}	{G}	180	
Benzo(g,h,i)perylene		25	{D}	{G}	9.3E+5	
Benzo(k)fluoranthene		0.0049	0.31{Q}	{G}	180	
Benzoic acid		31000	{D}	6.2E+5	1E+9{P}	
Benzyl alcohol		9800	22	2E+5	1.1E+8	
Benzyl chloride		0.21	{D}	4.2	2300	
bis(2-chloroethoxy)ethane		ID	{D}	ID	ID	
bis(2-chloroethyl)ether		0.032	4.2	0.64	350	
bis(2-ethylhexyl)phthalate		2.5	59{Q}	{G}	92000	
Boron		420{C}	{D}	8400{C}	1.6E+7	
Bromobenzene		ID	{D}	ID	ID	
Bromodichloromethane		0.56	24	11	6200	
Bromoform		4.6	65	92	50000	
Bromomethane		9.8	11	200	1.1E+5	

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Table 4-1 Michigan Act 307 Type A and B Criteria
MIANG, Alpena CRTC, Alpena, Michigan

Chemical	Groundwater Criteria			Soil Criteria		
	Type A Local Background Mean Value (ppb; dissolved metals)	Type B Health Based Drinking Water Value (ppb)	GSI Value (ppb)	Type B 20X Drinking Water Value (ppb)	Direct Contact Value (ppb)	Type A Default Value (ppb)
2-Butanone {MEK}		320	4100	6400	3.6E+6	
2-Butoxyethanol		ID	{D}	ID	ID	
t-Butyl alcohol		550	{D}	11000	6.1E+6	
Butyl benzyl phthalate		1100	{D}	22000	4.1E+7	
Cadmium	1.72	3.5{C}	0.64{C,E}	70{C}	1.3E+5	1200
Camphene		ID	{D}	ID	ID	
Caprolactam		5800	{D}	1.2E+5	2.2E+8	
Carbon disulfide		770	{D}	15000	8.6E+6	
Carbon tetrachloride		0.27	21	5.4	3000	
Chlordane		0.027	0.00053	{G}	1000	
Chloride		ID;250,000{R}	ID	{D}	5E+5{I}	ID
Chlorobenzene		130	71	2600	1.5E+6	
Chloroethane(methyl chloride)		9.1	{D}	180	1E+5	
2-Chloroethyl vinyl ether		ID	{D}	ID	ID	
Chloroform		5.6	43	110	62000	
Chloromethane		2.7	{D}	54	30000	
2-Chlorophenol		43	9.8	860	4.8E+5	
Chlorpyrifos		21	{D}	420	7.8E+5	
Chromium +3 {J}		37000{C}	77{C}	7.4E+5	3.9E+8	18000
Chromium +6 {J}	3.77	120{C}	7.3{C}	2400 {C}	1.2E+6	18000
Chrysene		0.0049	0.31{Q}	{G}	180	
Copper	4.71	1300{C};1000{R}	18{C,E}	20000{C}	9.8E+6	32000
Cyanazine		9.8	{D}	200	3.6E+5	
Cyanide (Free)		150	5.5	3000{C}	5.7E+6	390
Dacthal		5300	{D}	1.1E+5	2E+8	
4-4'-DDD		0.15	0.0084{Q}	{G}	5400	
4-4'-DDE		0.1	0.0059{Q}	{G}	3800	
4-4'-DDT		0.1	0.00023	{G}	3800	
Di-n-butyl phthalate		840	{D}	17000	3.1E+7	
Di-n-octyl phthalate		130	{D}	2600	4.7E+6	
Diacetone alcohol		ID	{D}	ID	ID	
Diazinon		0.63	{D}	13	23000	
Dibenzo(a,h)anthracene		0.0049	0.31{Q}	{G}	180	
Dibenzofuran		ID	{D}	ID	ID	
Dibromochloromethane		0.42	29	8.4	4700	
Dibromomethane		77	{D}	1500	8.6E+5	

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Table 4-1 Michigan Act 307 Type A and B Criteria
MIANG, Alpena CRTC, Alpena, Michigan

	Groundwater Criteria			Soil Criteria		
Chemical	Type A Local Background Mean Value (ppb; dissolved metals)	Type B Health Based Drinking Water Value (ppb)	GSI Value (ppb)	Type B 20X Drinking Water Value (ppb)	Direct Contact Value (ppb)	Type A Default Value (ppb)
1,2-Dichlorobenzene		600	7	12000	6.7E+6	
1,3-Dichlorobenzene		600	180	12000	6.7E+6	
1,4-Dichlorobenzene		1.5	15	30	16000	
3,3'-Dichlorobenzidine		0.077	0.063	1.5	2800	
Dichlorodifluoromethane		1600	{D}	32000	1.8E+7	
1,1-Dichloroethane		840	{D}	17000	9.3E+6	
1,2-Dichloroethane		0.38	560	7.6	4300	
1,1-Dichloroethylene		7	32{Q}	140	78000	
cis-1,2-Dichloroethylene		77	{D}	1500	8.6E+5	
trans-1,2-Dichloroethylene		120	300	2400	1.3E+6	
2,4-Dichlorophenol		21	34	420	7.8E+5	
2,4-Dichlorophenoxyacetic acid		70	47	1400	2.6E+6	
1,2-Dichloropropane		0.52	64	10	5800	
1,3-Dichloropropene {K}		0.2	3	4	2200	
Dichlorovos		0.12	{D}	2.4	4400	
Dicyclohexyl phthalate		ID	{D}	ID	ID	
Dieldrin		0.0022	3.2E-5	{G}	80	
Diethyl ether		3500	{D}	70000	3.9E+7	
Diethylene glycol monobutyl ether		84	{D}	1700	3.1E+6	
Diethyl phthalate		5200	1.25E+5{Q}	1E+5	1.9E+8	
Dimethyl phthalate		70000	2.9E+6{Q}	1.4E+6	1E+9 {P}	
N,N-Dimethylaniline		15	{D}	300	1.7E+5	
2,4-Dimethylphenol		350	31	7000	1.3E+7	
2,6-Dimethylphenol		4.2	{D}	84	1.6E+5	
3,4-Dimethylphenol		9.8	{D}	200	3.6E+5	
2,4-Dinitrotoluene		0.052	91{Q}	1	1900	
Dinoseb		7	0.5{F}	140	2.6E+5	
1,4-Dioxane		3.2	2000	64	35000	
Endosulfan {L}		1.6	0.056{Q}	{G}	60000	
Endrin		1.2	0.0023	{G}	44000	
Epichlorohydrin		3.5	{D}	70	39000	
Ethyl acetate		6300	1000	1.3E+5	7E+7	
Ethylbenzene		680;74{R}	31	1500	7.5E+6	
Ethylene dibromide		0.00042	1.1	0.0084	4.7	
Ethylene glycol		14000	68000	2.8E+5	5.2E+8	
Ethylene glycol acetate		ID	{D}	ID	ID	

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Table 4-1 Michigan Act 307 Type A and B Criteria
MIANG, Alpena CRTC, Alpena, Michigan

Chemical	Groundwater Criteria: Type A Local Background Mean Value (ppb; dissolved metals)	Groundwater Criteria: Type B Health Based Drinking Water Value (ppb)	Groundwater Criteria: GSI Value (ppb)	Soil Criteria: Type B 20X Drinking Water Value (ppb)	Soil Criteria: Direct Contact Value (ppb)	Soil Criteria: Type A Default Value (ppb)
1-Ethyl-2-methylbenzene		ID	{D}	ID	ID	
Fluoranthene		840	370{Q}	17000	3.1E+7	
Fluorene		840	14000{Q}	17000	3.1E+7	
Fluorine		2100{C};2000{R}	1900	42000{C}	1.6E+7	
Formaldehyde		1300	170	26000	1.4E+7	
Gentian violet		0.35	{D}	7	13000	
Heptachlor		0.0077	0.0016	{G}	280	
Heptachlor epoxide		0.0038	0.0011{Q}	{G}	140	
n-Heptane		31000	{D}	6.2E+5	3.4E+8	
Hexabromobenzene		20	{D}	400	7.3E+5	
Hexachlorobenzene (C-66)		0.022	0.0018	0.44	800	
Hexachlorobutadiene (C-46)		0.46	500{Q}	9.2	17000	
alpha-Hexachlorocyclohexane		0.0056	0.13{Q}	0.11	210	
beta-Hexachlorocyclohexane		0.02	0.46{Q}	0.4	720	
Hexachlorocyclopentadiene (C-56)		50	0.54	1000	1.8E+6	
Hexachloroethane		2.5	13	50	28000	
n-Hexane		2900	{D}	58000	3.2E+7	
2-Hexanone		980	{D}	20000	1.1E+7	
Indeno(1,2,3-cd)pyrene		0.0049	0.31{Q}	{G}	180	
Iron		ID;300{C,R}	{D}	6000{C}	ID	12000000
Isobutyl alcohol		2200	{D}	44000	2.5E+7	
Isophorone		38	860	760	4.3E+5	
Isopropyl alcohol		450	21000	9000	5E+6	
Lead	0.89	4{C,O}	6.6{C,E,Q}	80{C}	4E+5	21000
Lindane		0.027	0.08{Q}	0.54	1000	
Manganese		170{C};50{C,R}	{D}	1000{C}	1.2E+6	440000
Mercury (Inorganic)	0.17	2.1{C}	0.0013{C}	42{C}	78000	130
Methanol		3500	41000	70000	3.9E+7	
Methoxychlor		35	{D}	700	1.3E+6	
2-Methoxyethanol		28	{D}	560	3.1E+5	
4-Methyl-2-pentanone {MIBK}		350	{D}	7000	3.9E+6	
2-Methyl-4,6-dinitrophenol		2.4	0.59	48	91000	
2-Methyl-4-chlorophenoxyacetic acid		7	{D}	140	2.6E+5	
Methyl-tert-butyl ether (MTBE)		230	380	4600	2.6E+6	
Methylcylcopentane		ID	{D}	ID	ID	
Methylene chloride		4.6	59	92	51000	

wp\t4-1.775-06/15/95

Table 4-1 Michigan Act 307 Type A and B Criteria
MIANG, Alpena CRTC, Alpena, Michigan

	Groundwater Criteria			Soil Criteria		
Chemical	Type A Local Background Mean Value (ppb; dissolved metals)	Type B Health Based Drinking Water Value (ppb)	GSI Value (ppb)	Type B 20X Drinking Water Value (ppb)	Direct Contact Value (ppb)	Type A Default Value (ppb)
4,4'-Methylene-bis-2-chloroaniline {M}		0.035	{D}	{G}	1300	
2-Methylnaphthalene		ID	{D}	ID	ID	
2-Methylphenol		350	38	7000	3.9E+6	
3-Methylphenol		350	{D}	7000	1.3E+7	
4-Methylphenol		35	24	700	1.3E+6	
Metolachlor		1600	{D}	32000	6E+7	
Naphthalene		250	29	5000	9.3E+6	
Nickel	7.95	530{C}	57{C,E}	11000{C}	2E+7	20000
Nitrate		10000	{D}	2.0E+5	6.4E+7	
Nitrite		1000	{D}	20000	2.6E+7	
Nitrobenzene		3.2	1900{Q}	64	36000	
n-Nitroso-di-n-Propylamine		0.0049	{D}	0.098	54	
N-Nitrosodiphenylamine		7	160{Q}	140	78000	
Pendimethalin		840	{D}	17000	3.1E+7	
Pentachlorobenzene		5.8	{D}	120	2.2E+5	
Pentachlorophenol		0.29	0.8{F}	5.8	11000	
2-Pentene		ID	{D}	ID	ID	
Phenanthrene		25	{D}	500	9.3E+5	
Phenol		4200	1100	84000	4.7E+7	
Polybrominated biphenyls		0.0038	{D}	0.076	140	
Polychlorinated biphenyls {N}		0.018	2E-5	{G}	1000	
Prometon		150	{D}	3000	5.7E+6	
Propachlor		91	{D}	1800	3.4E+6	
Propazine		190	{D}	3800	7E+6	
Propyl alcohol		1300	8.2E+5	26000	1.5E+7	
Propylene glycol		1.4E+5	1.9E+5	2.8E+6	1E+9{P}	
Pyrene		520	11000	10000	1.9E+7	
Pyridine		7	20	140	78000	
Selenium	1.27	35{C}	5{C,Q}	700{C}	1.3E+6	410
Silver	1.27	33{C}	0.1{C}	660{C}	1.2E+6	1000
Sodium		1.5E+5	{D}	3E+6	1E+9{P}	
Styrene		1.2	19	24	13000	
Sulfate		ID	{D}	5E+6	ID	
Tebuthiuron		490	{D}	9800	1.8E+7	
1,2,4,5-Tetrachlorobenzene		2400	0.4	48000	8.8E+7	
2,3,7,8-Tetrachlorodibenzo-p-dioxin {S}		4.6E-7	1.4E-8	{G}	0.013	

wp\t4-1.775-06/15/95

Table 4-1 Michigan Act 307 Type A and B Criteria
MIANG, Alpena CRTC, Alpena, Michigan

	Groundwater Criteria			Soil Criteria		
Chemical	Type A Local Background Mean Value (ppb; dissolved metals)	Type B Health Based Drinking Water Value (ppb)	GSI Value (ppb)	Type B 20X Drinking Water Value (ppb)	Direct Contact Value (ppb)	Type A Default Value (ppb)
1,1,1,2-Tetrachloroethane		1.3	{D}	26	15000	
1,1,2,2-Tetrachloroethane		0.18	32	3.6	1900	
Tetrachloroethylene		0.7	22	14	7800	
Tetrahydrofuran		230	3300	4600	2.6E+6	
Thallium	10.75	0.58{C}	6.3{C,Q}	12{C}	22000	
Toluene		1500;790{R}	110	16000	1.7E+7	
p-Toluidine		0.18	{D}	3.6	6900	
Toxaphene		0.032	0.0002{Q}	0.64	350	
Triallate		91	{D}	1800	3.4E+6	
1,2,4-Trichlorobenzene		110	22	2200	1.2E+6	
1,1,1-Trichloroethane		200	120	4000	2.2E+6	
1,1,2-Trichloroethane		0.63	65	13	7000	
Trichloroethylene		2.2	94	44	24000	
Trichlorofluoromethane		2400	{D}	48000	2.7E+7	
2,4,5-Trichlorophenol		700	{D}	14000	2.6E+7	
2,4,6-Trichlorophenol		3.2	1.5	64	1.2E+5	
2(2,4,5-Trichlorophenoxy)propionic acid		52	21	1000	1.9E+6	
1,2,3-Trichloropropane		40	{D}	800	4.4E+5	
1,1,2-Trichloro-1,2,2-trifluoroethane		1.9E+5	{D}	3.8E+6	1E+9{P}	
Trifluralin		4.6	{D}	92	1.7E+5	
2,2,4-Trimethyl-2-pentene		ID	{D}	ID	ID	
1,3,5-Trimethylbenzene		ID	{D}	ID	ID	
tris(2,3-Dibromopropyl)phosphate		0.02	{D}	0.4	720	
Vanadium		61{C}	8{C}	1200{C}	2.2E+6	
Vinyl chloride		0.016	3.1	0.32	180	
Xylenes (dimethylbenzenes)		13000;280{R}	59	5600	1.4E+8	
Zinc	5.51	2300{C}	81{C,E};5000{R}	46000{C}	8.6E+7	47000

wp\t4-1.775-06/15/95

Table 4-1 Michigan Act 307 Type A and B Criteria
MIANG, Alpena CRTC, Alpena, Michigan

Chemical	Groundwater Criteria: Type A Local Background Mean Value (ppb; dissolved metals)	Groundwater Criteria: Type B Health Based Drinking Water Value (ppb)	Groundwater Criteria: GSI Value (ppb)	Soil Criteria: Type B 20X Drinking Water Value (ppb)	Soil Criteria: Direct Contact Value (ppb)	Soil Criteria: Type A Default Value (ppb)

Notes:

{A} Groundwater surface water interface (GSI) values are based on Rule 57 of Act 245. The values are presented only to establish groundwater criteria which are protective of surface water.
{B} Acceptable method detection limits for groundwater and soil samples, the latter expressed in µg/kg dry weight.
{C} Background, as defined in Rule 701(c), may be substituted as the cleanup criteria if higher than the Type B cleanup criterion.
{D} Chemical has either not been evaluated or an inadequate data base precludes the development of a GSI value. MDNR should be contacted to determine whether a chemical is being evaluated or has been evaluated since this list was prepared. If no value exists, the responsible party (RP) may develop a proposed GSI value for MDNR review and approval. Guidance can be obtained from MDNR. If a GSI value cannot be developed from data in the scientific literature, the RP can either perform a Type A cleanup or generate the minimum toxicity data required to develop the GSI value.
{E} GSI value is dependant on water hardness. Value presented was calculated assuming a hardness of 178 mg/ℓ of $CaCO_3$. If site-specific water hardness is expected to be significantly different, contact an Environmental Response Division (ERD) toxicologist.
{F} GSI value is pH dependant. Value presented was calculated assuming a pH of 7.7. If site-specific pH is expected to be significantly different, contact an ERD toxicologist.
{G} Chemical, due to its physicochemical properties, is not expected to leach through soils to groundwater under most conditions. Therefore, the direct contact soil criterion is considered to be protective of groundwater. However, the presence of organic solvents in the soil may increase the solubility of these chemicals, thereby increasing their potential to leach from soil to groundwater. Under these conditions site-specific leachate testing may be required.
{H} Professional judgement used to determine that 50 ppb of aluminum in drinking water is protective of human health.
{I} Criteria is based on agricultural impacts (phytotoxicity), not 20x groundwater criterion.
{J} All chromium data should be compared to the criteria for hexavalent chromium (Cr+6). Trivalent chromium (Cr+3) has the potential to be oxidized to Cr+6 in the presence of an oxidant such as chlorine at concentrations similar to these used to disinfect drinking water. Cr+3 criteria can be used only in these situations where Cr+6 is known/demonstrated not to exist at the site and use of the groundwater as a public water supply is prevented. If the data is presented as total chromium, hexavalent chromium criteria should be appplied.
{K} Criteria for 1,3-dichloropropene can be applied to the cis- and trans-1,3-dichloropropene isomers. The toxicity data used for criteria development were generated using a mixture of both isomers (Telone II).
{L} Criteria for endosulfan can be applied to endosulfan I (alpha-enodsulfan) and endosulfan II (beta-endosulfan).
{M} Also known as MBOCA.
{N} Criteria apply to each Aroclor separately (Aroclor 1016, 1221, 1232, 1242, 1248, 1254 and 1260).
{O} Higher level may be acceptable if soil concentration is less than 400 ppm and groundwater migrating off-site will not impact adjacent properties. Contact an ERD toxicologist for further explanation.
{P} Direct contact criterion is at saturation in soil. Criterion is actually greater than 100% in soil, hence it is reduced to 100 %.
{Q} Basis for the GSI value is the National Toxics Rule (NTR). The NTR value was either more restrictive than the Rule 57 Value or a Rule 57 Value was not available.

{R} Value is the aesthetic drinking water value. Most restrictive value applies.
{S} Local background concentration is higher than Type B criteria and is therefore substituted as the cleanup criterion.
ID = Inadequate data to develop health based criterion.
NA = Not available.

wp\t4-1.775-06/15/95

4.1.1 Type A: Clean-up Criteria

Type A criteria is attained when either of the following conditions is met:

- The hazardous substance concentration does not exceed "background"
- The hazardous substance concentration does not exceed the "MDL" for the substance in question.

MDNR allows the use of local background levels for those instances where the local background exceeds the Type A or Type B cleanup criteria.

The MDNR has established default Type A soil values for 17 metals. These default values may be used in lieu of site-specific soil background concentrations. Site-specific background data were collected at Alpena CRTC and background concentrations were calculated according to MDNR requirements. The calculated background concentrations were lower than the Type A default values; therefore the Type A default values were used in the assessment. Type A default values are presented in Table 4-1. The site-specific background data is presented in Appendix M.

Background concentrations for metals in groundwater were calculated using four rounds of groundwater data from site-specific up gradient wells. Site-specific up gradient wells which had organic compounds above the detection limit were eliminated from the data set. The background concentrations were then defined as the mean of the four rounds of groundwater data from the remaining up gradient wells. These calculated mean values are presented in Table 4-1. The data set used to generate the background concentrations is presented in Appendix M.

4.1.2 Type B Clean-up Criteria

Type B cleanup criteria are discussed below for groundwater, soils, and surface water.

Groundwater

Type B cleanup criteria are attained when a hazardous substance concentration in an aquifer does not exceed the <u>lowest</u> of the following:

- Carcinogens – the concentration that represents an increased lifetime cancer risk of 1 in 1,000,000 (equations for calculations of the carcinogenic risk are provided in Public Act 307, R 299.5723) (State of Michigan, 1990)
- Non-carcinogens – the concentration which represent the human life cycle safe concentration (equations for calculations on non-carcinogenic risk are provided in Public Act 307, R 299.5725) (State of Michigan, 1990)

- A secondary MCL
- The concentration documented as the taste or odor threshold or the concentration below which appearance or other aesthetic characteristics are not adversely affected.

The equations provided in the rules to calculate acceptable concentrations for both carcinogens and non-carcinogens are based on 70-kg (154 lbs) individuals (adults) ingesting 2 L (0.5 gal) of water per day for a lifetime.

For non-carcinogens, maximum contaminant levels (MCLs) and USEPA-established final lifetime health advisories are considered acceptable concentrations for a Type B cleanup. When MCLs or final lifetime health advisories are not available, the acceptable concentrations must be calculated using the equations provided in the rules.

The point of exposure can be any point in the aquifer. Therefore, to meet the Type B cleanup criteria, the maximum concentration (not the average concentration) must meet the criteria.

Groundwater that is not in an aquifer (for example, water held in the pores of a clay unit) shall be addressed by using a Type B cleanup criteria for soil. However, if contaminated non-aquifer groundwater is transported to an aquifer, that groundwater must be addressed by using a Type B cleanup criteria for groundwater in aquifers.

Surface Water

The surface water criteria actually applies to groundwater. A hazardous substance concentration in groundwater shall not result in a discharge to surface water that exceeds the limits that would apply under Rule 323.1057 1929 Act 245 (Rule 57) (Michigan, 1929). The Rule 57 values have been identified as the GSI values. GSI values listed in Table 4-1 have been developed for surface water which is not used as a drinking water source.

The Rule 57 requires that the GSI value not be exceeded at a point where groundwater naturally discharges to surface water. Compliance with this rule may be made by monitoring at the GSI or by predictive modeling. The GSI values apply for protection of aquatic life only and are not applied to human exposure to surface water.

Soils

Type B cleanup criteria for soils states that soils must be remediated so that they are no longer a threat to groundwater quality, surface water quality, air quality, or human health. In addition, the soil must not be restricted in terms of its use as a natural resource.

Contaminated Soils as a Threat to Groundwater Quality

To assure that soils do not pose a threat to groundwater, the concentration of a hazardous substance in soil shall be below that which produces a concentration in leachate that is equal to the highest of the following:

- Background groundwater concentrations (Type A)
- The MDL (Type A)
- The concentration that represents an increased cancer risk of 1 in 1,000,000 (Type B)
- The concentration which represents the human life cycle safe concentration (Type B)
- The secondary MCL (Type B)
- The concentration documented as the taste or odor threshold or the concentration below which appearance or other aesthetic characteristics are not adversely affected (Type B)
- Leachate concentration generated by background soil.

Leachate testing is not required if the total concentration of a hazardous substance in soil does not exceed 20 times the above criteria. When leachate testing is required, the EPAs TCLP can be used. The MDNR may approve other methods if they more accurately simulate site conditions.

Contaminated Soil as a Threat to Surface Water

To assure the protection of surface water from transport or runoff of contaminated soil, measures shall be implemented to prevent hazardous substance levels in surface water that exceed relevant water quality standards specified in Act 245 of the Public Acts of 1929 (Michigan, 1929). The only exception to Act 245 is that no mixing zone is allowed under the Act 307 rules.

Contaminated Soil as a Threat to Human Health

To assure the protection of human health due to inhalation and/or direct contact with contaminated soils, hazardous substance concentrations shall not exceed those that cause an increased lifetime cancer risk of 1 in 1,000,000, or "other injurious effects." "Other injurious effects" are not defined in the rules.

Equations for risk calculations are included in Public Act 307 R 299.5711 (Michigan, 1990) for direct contact (ingestion and dermal exposure). They assume an ingested dose of 0.09 grams (0.03 oz) of soil per day and a dermal contact dose of 0.9 grams (.03 oz) of soil per day for a 70-kilogram (154-pound) adult. Absorption efficiencies are provided for cases where chemical-specific data are not available.

Contaminated Soil as a Threat to Air Quality

To assure the protection of air quality, hazardous substance concentrations shall not produce any emission which results in a violation of the provisions of Act 348 of the Public Acts of 1965 (Michigan, 1965).

4.1.3 Type C: Clean-up Criteria

Type C cleanup criteria are developed on a site-specific basis, using site-specific exposure scenarios. Anyone proposing a Type C cleanup must demonstrate that the proposed criteria are appropriate for the site, and the Type C cleanup criteria shall take into account "reasonably foreseeable" uses of the site and natural resources in question.

4.2 RATIONALE FOR DEVELOPMENT OF DATA BASE FOR RISK ASSESSMENT APPLICATION

Chemicals of potential concern were initially selected on a site-specific basis based on MDNR Act 307 Type A or B cleanup criteria. Data sets were developed for those chemicals which exceed the Type A or B cleanup criteria. The methodology for development of these data sets is outlined below.

All analytical data were validated according to EPA Functional Guidelines for Evaluating Organic and Inorganic Analyses (EPA, 1992b, 1988a). The validation is presented in Appendix K. All samples were evaluated using the five and ten times rule for blank contamination. Those data found to be laboratory or field artifacts were qualified with a B, indicating blank contamination, and were not included in the data base.

Soil

The most recently collected soil data (November, 1992 and September, 1993) were used in the selection of chemicals of concern. Those metals exceeding the Type A default values were considered chemicals of potential concern. Organic compounds which exceeded the Type B cleanup criteria for soil, defined as 20 times the drinking water value, were selected as chemicals of potential concern.

In generating the final data set, those chemicals of concern which were non detect (qualified U) in a given sample were assigned a value of one half of the sample quantitation limit (SQL). Duplicate sample results were averaged with the original sample results and the average value used as a single sample result.

Groundwater

The most recently collected groundwater data (August and September, 1993) were used to select chemicals of potential concern. Historical groundwater data from 1987, 1988, and 1991 were deemed not current and were not used in the assessment. Filtered groundwater data were used to select chemicals of potential concern based on the natural turbidity of the shallow aquifer and the likelihood that the water would require filtration prior to use, as suggested by MDNR toxicologists and in keeping with EPA risk assessment guidance. The Type B cleanup criteria for metals in groundwater allows the use of local background values (Type A criteria) if higher than the Type B cleanup level. Background levels for metals were

calculated for the facility, as described previously in Section 4.1.1. Those metals exceeding the Type A background cleanup criteria were considered chemicals of potential concern. Organic compounds which exceeded the Type B cleanup criteria for groundwater were selected as chemicals of potential concern.

In generating the final data set, those chemicals of concern which were non-detect (qualified U) in a given sample were assigned a value of one half of the SQL. Duplicate sample results were averaged with the original sample results and the average value used as a single sample result.

Surface Water

The most recently collected (August and September, 1993) surface water data were used to select chemicals of potential concern. Those compounds exceeding the acceptable MDL, as defined in Act 307 Type B cleanup criteria, Memorandum 8, Revision 3, February 1994 , were identified as chemicals of potential concern.

In generating the final data set, those chemicals of concern which were non-detect (qualified U) in a given sample were assigned a value of one half of the SQL. Duplicate sample results were averaged with the original sample results and the average value used as a single sample result.

No surface water samples were collected from Lake Winyah or the Thunder Bay River. For those sites where these surface water bodies are potential exposure pathways the GSI concept was used to approximate surface water contaminant concentrations. The concentrations of contaminants detected in the groundwater at the monitoring well location nearest to the surface water body were used as surface water concentrations. This procedure is more conservative than sampling the surface water body, as the concentrations of chemicals that a human would actually be exposed to in the surface water are lower than the GSI point due to dilution by the sheer size of the water body.

Sediment

The most recently collected sediment data (August and September, 1993) were used to select chemicals of potential concern. No MDNR Act 307 criteria exist for sediments, therefore the following criteria were used to identify chemicals of concern:

- All organic compounds detected above the acceptable MDL are considered chemicals of concern
- Metals were identified as chemicals of potential concern if they were present above background levels in soils.

4.3 EXPOSURE ASSESSMENT

The objective of the exposure assessment is to estimate the type and magnitude of exposure to the chemicals of potential concern that are present at or migrating from the site. The components of an exposure assessment include: 1) characterization of the exposure setting, 2) identification of exposure pathways, and 3) quantification of exposure.

Exposure assessments were developed for each site within the Alpena CRTC for which chemicals of potential concern were identified. Exposure pathways were identified for both current and future land-use scenarios. Intake models for site-specific exposure pathways are provided in Section 4.7 through 4.14.

Reasonable maximum exposure concentrations for soil, groundwater, surface water, and sediment were determined by calculating the 95 percent upper confidence limit (UCL) of the arithmetic mean concentration for each chemical of potential concern. In those cases where the 95 percent UCL exceeded the maximum detected concentrations of a chemical, then the maximum detected concentration was used as the reasonable maximum exposure concentration.

Future down gradient groundwater exposure concentrations and future groundwater to surface water exposure concentration were determined by predicting the peak future groundwater concentrations using a two dimensional method of characteristics (MOC) solute transport model (Konikow, Dredehoft, and Goode, 1989). The maximum concentration modeled over time was used as the future reasonable maximum exposure concentration.

The concentration of chemicals volatilized to the atmosphere from soils was determined by estimating the exposure point concentration using the Research Triangle Institute Open Model Landfill Model (Environmental Protection Agency [EPA], 1990; Farmer, 1978) to estimate emission rates from freshly excavated soil. This model is a worst case scenario which assumes no soil cap through which vapors must defuse.

The chemical concentration in resuspended dust was estimated based on dust loading factors (Department of Energy, 1989) of 600 g/m^3 and 400 g/m^3 for construction work and construction traffic. It was assumed that no dilution of particles takes place over distance.

4.4 TOXICITY ASSESSMENT

A toxicity assessment of chemicals of potential concern which were identified for one or more sites and the known carcinogenic and noncarcinogenic effects are presented. The information presented in this section was gathered from sources which are referenced with the actual toxicity values presented in tabular form later in this section.

4.4.1 Toxicity Profiles

Toxicity information for both human and ecological receptors is included in the following paragraphs.

Chemicals of concern were classified into several categories according to their similarity in chemical structure and/or physiochemical properties. The chemical categories and the chemicals of concern within each category are listed below:

- VOCs: benzene, styrene, 1,4 dichlorobenzene, tetrachloroethne, and trichloroethylene, bromodichloromethane, dibromochloromethane, 1,2 dichloroethane, carbon tetrachloride, methylene chloride

- SVOCs: PAHs including phenanthrene, benzo (a) anthracene, chrysene, benzo (b) fluoranthene, benzo (k) fluoranthene, benzo (a) pyrene, carbazole and indeno (1,2,3-cd) pyrene 2-methylnapthalene; dibenzofuran, methylphenol

- Metals: Antimony, arsenic, chromium, copper, lead, selenium.

Arsenic – Arsenic has been associated with skin, lung, and liver cancers in humans. Acute arsenic poisoning can cause nausea, vomiting, and diarrhea. In severe cases, arsenic poisoning may produce shock followed by coma and death. Chronic arsenic poisoning may cause disturbances of the digestive system, liver damage, and disturbances of the blood, kidneys, or nervous system.

Arsenic is toxic to aquatic animal species, and induces its toxic effects via enzyme inhibition. In aquatic species, arsenic has induced death following acute exposures and has caused death and deformity following chronic exposures. Arsenic can bioaccumulate in aquatic vertebrates and invertebrates, but bioconcentration occurs to a greater extent in invertebrates. Quantitative data on the toxicity of arsenic to terrestrial wildlife species are limited, but arsenic has been shown to induce death in wild rabbits and hares following acute oral exposures. In laboratory species, arsenic has been found to be carcinogenic, teratogenic, embryotoxic, and fetotoxic.

Benzene – Benzene is readily absorbed following oral and inhalation exposure, and is a known human carcinogen. The toxic effects of benzene in humans following exposure by inhalation is the same as that for laboratory animals, and includes central nervous system effects, hematological effects, and immune system depression. In humans, acute exposures to high concentrations of benzene vapors has been associated with dizziness, nausea, vomiting, headache, drowsiness, narcosis, coma, and death. Chronic exposure to benzene vapors can produce reduced leukocyte, platelet, and red blood cell levels. Chronic exposure to benzene is also associated with leukemia and bone marrow damage. In addition, the compound is a central nervous system depressant at high concentrations, and may cause acute narcotic reactions.

Data are not considered sufficient to develop ambient water quality criteria for benzene. No information is available on the toxicity of benzene to terrestrial wildlife, domestic animals, or birds. Toxic effects in laboratory animals include central nervous system effects, hematological effects, and immune system depression.

Carbon Tetrachloride – Noncarcinogenic effects of carbon tetrachloride exposure are primarily associated with hepatoxicity. Chronic oral exposure of rats as well as several other species to carbon tetrachloride results in liver enlargement, necrosis, (i.e., cell death), cirrhosis (i.e.,

hardening of liver tissues) and the formation of liver lesions. Kidney damage may also occur. Evidence also suggests that alcoholism enhances susceptibility to carbon tetrachloride toxicity.

Carbon tetrachloride is classified as a probable human carcinogen, based on the results of several animal studies demonstrating an increase in liver cancer following chronic oral exposure (i.e., by gavage).

Chromium – Following oral exposure, absorption in humans of Cr(III) is low while absorption of Cr(VI) is high. Chromium is an essential micronutrient and is not toxic in trace quantities. High levels of soluble Cr(VI) and Cr(III) can produce kidney and liver damage following acute oral exposure; organs affected by chronic oral exposure remain unidentified. Chronic inhalation exposure may cause respiratory system damage in humans. Furthermore, epidemiological studies of worker populations have clearly established that inhaled Cr(VI) is a human carcinogen; the respiratory passages and lungs are the target organs. Inhalation of Cr(III) or ingestion of Cr(VI) or Cr(III) has not been associated with carcinogenicity in humans.

Chromium is bioaccumulated by aquatic organisms, and passage of chromium through the food chain has been demonstrated. Chromium has a low inherent toxicity to fish and animals, moderate toxicity to plants, and low potential for biomagnification in the food chain. Chromium is an essential trace element for animals and is considered non-essential for plants.

Copper – Copper has a low potential for biomagnification in the food chain, low inherent toxicity to animals, and a high inherent toxicity to fish and plants. Toxicity of copper to aquatic life is enhanced at low water alkalinity. Although copper is highly toxic to fish and freshwater algae, mammals and birds have physiological barriers to copper absorption and are more resistant to copper toxicity than more primitive animals.

1,2-Dichloroethane – Exposure to high levels of 1,2-DCA has been shown to cause heart, lung, liver and nervous disorders. Human exposures occur primarily in the industrial workplace.

Local effects include dermatitis and eye damage, including cornial opacity. Systemic effects include nausea, vomiting, mental confusion, dizziness, pulmonary edema, liver and kidney damage. Acute exposures can lead to death from respiratory and circulatory failure.

Lead – Lead is a probable human carcinogenic and is stored in humans in bone, kidneys, and liver. The major adverse effects in humans caused by lead include alterations in the hematopoietic and nervous systems. The toxic effects are generally related to the concentration of this metal in blood. Toxic blood concentration in children and in sensitive adults can cause severe, irreversible brain damage, encephalopathy, and possible death. Physiological and biochemical effects that occur even at low levels include enzyme inhibition, elevated erythrocyte protoporphyrin, interference with vitamin D metabolism, cognitive dysfunction in infants, electrophysiological dysfunction, and reduced childhood growth.

Lead is generally considered a highly toxic contaminant because it is not an essential nutrient to either plants or animals. Lead bioaccumulates in animal tissues, but has low potential for animal in the food chain. The solubility of lead is dependent on water hardness, and lead is

considered 20 to 100 times more toxic in soft water. In aquatic environments, most lead is found in bottom sediments and is therefore a concern more in benthic organisms than in planktonic or pelagic forms. Toxicity of lead in water is dependent on ph, organic materials, and the presence/absence of other metals.

The primary mechanism of acute toxicity of lead to freshwater organisms is unkown. Invertebrate species appear more sensitive than vertebrate species. Lead inhibits plant growth and reduces photosythesis, mitosis, and water absorption.

Methylene chloride – Methylene chloride is a mild narcotic in high concentrations. Effects from intoxication with methylene chloride include: headache, giddiness, stupor, irritability, numbness and tingling of the limbs. Exposure to methylene chloride in liquid and vapor forms causes irritation to the eyes and upper respiratory passages. Contact of the liquid to skin may cause burns.

Tetrachloroethylene (or Perchloroethylene) – PCE is a probable human carcinogen.

Trichloroethylene – TCE has been classified as a probable human carcinogen. Chronic exposure to TCE may affect the central nervous system and cause minor liver function impairments. Short-term high-level concentrations of TCE may cause depression of the central nervous system, kidney and liver damage, cardiovascular damage, and death due to ventricular fibrillation. Short-term, low-level exposure may cause irritation of the eyes, nose, throat, and skin. TCE may bioaccumulate in organisms, but it does not appear to biomagnify in the food chain.

4.4.2 Toxicity Values

This section presents a discussion of the derivation and meaning of toxicity values. Noncarcinogenic toxicity values are discussed in Section 4.4.2.1 and the carcinogenic toxicity values are discussed in Section 4.4.2.2.

4.4.2.1 Noncarcinogenic Toxicity Values

This section presents a discussion of the derivation and meaning of carcinogenic and noncarcinogenic toxicity values. Carcinogenic and noncarcinogenic toxicity values of chemicals of potential concern, plus other pertinent toxicity information, are summarized in tabular form.

A reference dose, or RfD, is the toxicity value most often used to evaluate noncarcinogenic effects resulting from exposure to contaminants. A chronic RfD is defined as an estimate (with uncertainty spanning an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deliterious noncarcinogenic effects during a lifetime. Chronic RfDs should be used to evaluate potential noncarcinogenic effects for an exposure period of 7 years to a lifetime (i.e., 70 years). Chronic RfDs are used to evaluate potential noncarcinogenic effects for both the resident child and adult.

The EPA has developed RfDs for both the oral exposure route and the inhalation exposure route. Because completed exposure pathways identify exposure to chemicals of potential concern through the oral and inhalation route, both RfDs will be discussed.

For the oral RfD, the EPA examines all available animal and human toxicological studies for a chemical following exposure by the oral route. If adequate human data are available, this information is used. If no adequate human data are available, animal study data are used. If only animal study data are available, EPA selects the study on the most sensitive animal species as the critical study for the basis of the RfD. The most sensitive species is that species showing a toxic effect at the lowest administered dose.

Once the critical study and toxic effect have been selected, the EPA identifies the no-observed-adverse-effect level (NOAEL) for the study. The NOAEL is the exposure level which represents the highest level tested at which no adverse effects, including the critical effect, were demonstrated. In some studies, only a lowest-observed-adverse-effect level (LOAEL) is available. The EPA may use the LOAEL to determine the RfD, but this increases the uncertainty in the RfD value.

The RfD is calculated from the NOAEL, or LOAEL if a NOAEL is not available, by application of uncertainty factors (UFs) and a modifying factor (MF). UFs usally consist of multiples of 10. Each UF represents a specific area of uncertainty which the EPA establishes in extrapolation from available data. The following UFs are applied to the extrapolated data:

- UF of 10 to account for variation in the general human population. This UF is intended to protect sensitive subpopulations, such as the elderly or children

- UF of 10 to account for extrapolation from animal studies to human studies

- UF of 10 to account for a NOAEL which is derived from a subchronic rather than a chronic study

- UF of 10 to account for the use of a LOAEL rather than a NOAEL.

In addition of UFs, a MF ranging from >0 to 10 is used to reflect a qualitative professional assessment of additional uncertainties in the critical study selected and in the entire data base applicable to the critical study.

The EPA calculates a chronic RfD by dividing the NOAEL, or LOAEL if no NOAEL is available, by the products of all applicable UFs and the MF. RfDs are expressed in units of milligrams(s) per kilogram (mg/kg-day). Most oral RfDs are based on administered doses rather than abosorbed doses.

Tables 4-2 and 4-3 present the oral and inhalation RfD respectively for potential noncarcinogenic effects of those chemicals identified as chemicals of potential concern. Where available, RfDs were obtained from the EPA Integrated Risk Information System (IRIS) as a first source (EPA, 1993). If an RfD has not been published in IRIS, the EPA's Health Effects Assessment Summary Tables (HEAST) was used as a second source (EPA, 1993).

Table 4-2 Toxicity Values: Potential Noncarcinogenic Effects
MIANG, Alpena CRTC, Alpena, Michigan

Oral							
PARLABEL	Chemical	RfD (mg/kg-day)	Confidence Level	Critical Effects	Uncertainty and Modifying Factors (c)	Date Checked (IRIS)	Project
ANTH	Anthracene	Chronic: 3×10^{-1} (a) Subchronic: 3 (b)	Low	No observed effects	UF = 3,000 MF = 1	03/01/93	M
SB	Antimony	Chronic: 4×10^{-4} (a) Subchronic: 4×10^{-4} (b)	Low	Reduced lifespan; altered blood chemistries	UF = 1,000 MF = 1	12/07/93	Alpena
AS	Arsenic	Chronic: 3×10^{-4} (a) Subchronic: 3×10^{-4} (b)	Medium	Keratosis; hyperpigmentation	UF = 3 MF = 1	12/07/93	Alpena
BZ	Benzene	ND	NA	NA	NA	12/07/93	Alpena
BZAA	Benzo(a)anthracene	Chronic: 3×10^{-2} (d) Subchronic: 3×10^{-1} (e)	NA	NA	NA	12/07/93	Alpena
BZAP	Benzo(a)pyrene	Chronic: 3×10^{-2} (d) Subchronic: 3×10^{-1} (e)	NA	NA	NA	12/07/93	Alpena
BZBF	Benzo(b)fluoranthene	Chronic: 3×10^{-2} (d) Subchronic: 3×10^{-1} (e)	NA	NA	NA	12/07/93	Alpena
BZKF	Benzo(k)fluoranthene	Chronic: 3×10^{-2} (d) Subchronic: 3×10^{-1} (e)	NA	NA	NA	12/07/93	Alpena
BZGHIP	Benzo(g,h,i)perylene	Chronic: 3×10^{-2} (d) Subchronic: 3×10^{-1} (e)	NA	NA	NA	03/01/93	M

Key:

ND = No Data
NA = Not Available
UF = Uncertainty Factor
MF = Modifying Factor

(a) Retrieved from IRIS, 1993.
(b) Retrieved from HEAST, Annual FY92. FY93 used for Alpena
(c) UFs and MFs are for chronic RfDs.
(d) Chronic RfD for pyrene was used.
(e) Subchronic RfD for pyrene was used.
(f) Chronic RfD for DDT was used.
(g) Subchronic RfD for DDT was used.
(h) RfD calculated from conversion of 1.3 mg/L drinking water standard.
(i) RfD equal to chronic RfD.
(j) Data for total chlordane used.
(k) The value for Cr+6 rather Cr+3 was used as a worst-case toxicity value.
(l) Data for 2,3,7,8-TCDD used per California EPA, 1992a.
(m) Oral RfD for TCE provided by California EPA, 1992c.

wp/t4-2.775-06/15/95

Table 4-2 Toxicity Values: Potential Noncarcinogenic Effects
MIANG, Alpena CRTC, Alpena, Michigan

Oral							
PARLABEL	Chemical	RfD (mg/kg-day)	Confidence Level	Critical Effects	Uncertainty and Modifying Factors (c)	Date Checked (IRIS)	Project
BDCME	Bromodichloromethane	Chronic: 2×10^{-2} (a) Subchronic: 2×10^{-2} (b)	Medium	Renal cytomegaly	UF = 1,000 MF = 1	12/07/93	Alpena
CTCL	Carbon Tetrachloride	Chronic: 7×10^{-4} (a) Subchronic: 7×10^{-3} (b)	Medium	Liver lesions	UF = 1,000 MF = 1	12/07/93	Alpena
CLBZ	Chlorobenzene	Chronic: 2×10^{-2} (a) Subchronic: 2×10^{-1} (b)	Medium	Histopathologic changes in the liver	UF = 1,000 MF = 1	10/15/93	M
CR	Chromium, Total (k)	Chronic: 5×10^{-3} (a) Subchronic: 2×10^{-2} (b)	Low	No effects observed	UF = 500 MF = 1	12/07/93	Alpena
CHRYSENE	Chrysene	Chronic: 3×10^{-2} (d) Subchronic: 3×10^{-1} (e)	NA	NA	NA	12/07/93	Alpena
CU	Copper	Chronic: 3.7×10^{-2} (h) Subchronic: 3.7×10^{-2} (i)	NA	Local gastrointestinal irritation	NA	12/07/93	Alpena
DNBP	Di-n-butl Phthalate	Chronic: 1×10^{-1} (a) Subchronic: 1 (b)	Low	Increased mortality	UF = 1,000 MF = 1	03/02/93	M
DBF	Dibenzofuran	ND	NA	NA	NA	12/07/93	Alpena
DBCME	Dibromochloromethane	Chronic: 2×10^{-2} (a) Subchronic: 2×10^{-1} (b)	Medium	Hepatic lesions	UF = 1,000 MF = 1	12/07/93	Alpena
DCA12	1,2-Dichloroethane	ND	NA	NA	NA	10/15/93	M

Key:

ND = No Data
NA = Not Available
UF = Uncertainty Factor
MF = Modifying Factor

(a) Retrieved from IRIS, 1993.
(b) Retrieved from HEAST, Annual FY92. FY93 used for Alpena
(c) UFs and MFs are for chronic RfDs.
(d) Chronic RfD for pyrene was used.
(e) Subchronic RfD for pyrene was used.
(f) Chronic RfD for DDT was used.
(g) Subchronic RfD for DDT was used.
(h) RfD calculated from conversion of 1.3 mg/L drinking water standard.
(i) RfD equal to chronic RfD.
(j) Data for total chlordane used.
(k) The value for Cr+6 rather Cr+3 was used as a worst-case toxicity value.
(l) Data for 2,3,7,8-TCDD used per California EPA, 1992a.
(m) Oral RfD for TCE provided by California EPA, 1992c.

wp/t4-2.775-06/15/95

Table 4-2 Toxicity Values: Potential Noncarcinogenic Effects
MIANG, Alpena CRTC, Alpena, Michigan

Oral							
PARLABEL	Chemical	RfD (mg/kg-day)	Confidence Level	Critical Effects	Uncertainty and Modifying Factors (c)	Date Checked (IRIS)	Project
DCBZ14	1-4-Dichlorobenzene	ND	NA	NA	NA	12/07/93	Alpena
EBZ	Ethylbenzene	Chronic: 1×10^{-1} (a) Subchronic: 1 (b)	Low	Liver and kidney toxicity	UF = 1,000 MF = 1	03/02/93	M
FLA	Fluoranthene	Chronic: 4×10^{-2} (a) Subchronic: 4×10^{-1} (b)	Low	Nephropathy, increased liver weights, hematological alterations, and clinical effects	UF = 3,000 MF = 1	03/02/93	M
INP123	Indeno(1,2,3-cd)pyrene	Chronic: 3×10^{-2} (d) Subchronic: 3×10^{-1} (e)	NA	NA	NA	12/07/93	Alpena
PB	Lead	ND	NA	NA	NA	12/07/93	Alpena
MTNPH2	2-Methylnaphthalene	Chronic: 3×10^{-2} (d) Subchronic: 3×10^{-1} (e)	NA	NA	NA	12/07/93	Alpena
MEPH4	4-Methylphenol (p-Cresol)	Chronic: 5×10^{-3} (b) Subchronic: 5×10^{-2} (b)	NA	Decreased body weights and neurotoxicity	UF = 1,000 MF = 1	05/06/93	M
MTLNCL	Methylene Chloride	Chronic: 6×10^{-2} (a) Subchronic: 6×10^{-2} (b)	Medium	Liver toxicity	UF = 100 MF = 1	03/02/93	M
NI	Nickel	Chronic: 2×10^{-2} (a) Subchronic: 2×10^{-2} (b)	Medium	Decreased body and organ weights	UF = 300 MF = 1	04/02/93	M

Key:

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NA = Not Available
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MF = Modifying Factor

(a) Retrieved from IRIS, 1993.
(b) Retrieved from HEAST, Annual FY92. FY93 used for Alpena
(c) UFs and MFs are for chronic RfDs.
(d) Chronic RfD for pyrene was used.
(e) Subchronic RfD for pyrene was used.
(f) Chronic RfD for DDT was used.
(g) Subchronic RfD for DDT was used.
(h) RfD calculated from conversion of 1.3 mg/L drinking water standard.
(i) RfD equal to chronic RfD.
(j) Data for total chlordane used.
(k) The value for Cr+6 rather Cr+3 was used as a worst-case toxicity value.
(l) Data for 2,3,7,8-TCDD used per California EPA, 1992a.
(m) Oral RfD for TCE provided by California EPA, 1992c.

wp/t4-2.775-06/15/95

Table 4-2 Toxicity Values: Potential Noncarcinogenic Effects
MIANG, Alpena CRTC, Alpena, Michigan

Oral							
PARLABEL	Chemical	RfD (mg/kg-day)	Confidence Level	Critical Effects	Uncertainty and Modifying Factors (c)	Date Checked (IRIS)	Project
PHAN	Phenanthrene	Chronic: 3×10^{-2} (d) Subchronic: 3×10^{-1} (e)	NA	NA	NA	12/07/93	Alpena
PYR	Pyrene	Chronic: 3×10^{-2} (a) Subchronic: 3×10^{-1} (b)	Low	Kidney effects	UF = 3,000 MF = 1	03/02/93	M
SE	Selenium	Chronic: 5×10^{-3} (a) Subchronic: 5×10^{-3} (b)	High	Clinical selenosis	UF = 3 MF = 1	12/07/93	Alpena
STY	Styrene	Chronic: 2×10^{-1} (a) Subchronic: ND	Medium	Red blood cell and liver effects	UF = 1,000 MF = 1	12/07/93	Alpena
PCE	Tetrachloroethene	Chronic: 1×10^{-2} (a) Subchronic: 1×10^{-1} (b)	Medium	Hepatotoxicity; Weight gain	UF = 1,000 MF = 1	12/07/93	Alpena
TCE	Trichloroethene	Chronic: 7.35×10^{-3} (m) Subchronic: 7.35×10^{-3} (i)	NA	NA	NA	12/07/93	Alpena
VC	Vinyl Chloride	ND	NA	NA	NA	12/07/93	Alpena
ZN	Zinc	Chronic: 3×10^{-1} (a) Subchronic: 3×10^{-1} (b)	Medium	40% decrease in erthrocyte Superoxide dismutase (ESOD) concentration in adult females after 10 weeks of zinc exposure	UF = 3 MF = 1	12/07/93	Alpena

Key:

ND = No Data
NA = Not Available
UF = Uncertainty Factor
MF = Modifying Factor

(a) Retrieved from IRIS, 1993.
(b) Retrieved from HEAST, Annual FY92. FY93 used for Alpena
(c) UFs and MFs are for chronic RfDs.
(d) Chronic RfD for pyrene was used.
(e) Subchronic RfD for pyrene was used.
(f) Chronic RfD for DDT was used.
(g) Subchronic RfD for DDT was used.
(h) RfD calculated from conversion of 1.3 mg/L drinking water standard.
(i) RfD equal to chronic RfD.
(j) Data for total chlordane used.
(k) The value for Cr+6 rather Cr+3 was used as a worst-case toxicity value.
(l) Data for 2,3,7,8-TCDD used per California EPA, 1992a.
(m) Oral RfD for TCE provided by California EPA, 1992c.

wp/t4-2.775-06/15/95

Table 4-3 Toxicity Values: Potential Noncarcinogenic Effects
MIANG, Alpena CRTC, Alpena, Michigan

Inhalation

PARLABEL	Chemical	RfD (c) (mg/kg-day)	Confidence Level	Critical Effects	Uncertainty and Modifying Factors (d)	Date Checked (IRIS)	Project
ANTH	Anthracene	Chronic: 5.7×10^{-4} (h) Subchronic: 5.7×10^{-4} (f)	NA	NA	NA	03/01/93	M
SB	Antimony	Chronic: 4×10^{-4} (i) Subchronic: 4×10^{-4} (j)	NA	NA	NA	12/07/93	Alpena
AS	Arsenic	Chronic: 3×10^{-4} (i) Subchronic: 3×10^{-4} (j)	NA	NA	NA	12/07/93	Alpena
BZ	Benzene	ND	NA	NA	NA	12/07/93	Alpena
BZAA	Benzo(a)anthracene	Chronic: 3×10^{-2} (i) Subchronic: 3×10^{-1} (j)	NA	NA	NA	12/07/93	Alpena
BZAP	Benzo(a)pyrene	Chronic: 3×10^{-2} (i) Subchronic: 3×10^{-1} (j)	NA	NA	NA	12/07/93	Alpena
BZBF	Benzo(b)fluoranthene	Chronic: 3×10^{-2} (i) Subchronic: 3×10^{-1} (j)	NA	NA	NA	12/07/93	Alpena
BZKF	Benzo(k)fluoranthene	Chronic: 3×10^{-2} (i) Subchronic: 3×10^{-1} (j)	NA	NA	NA	12/07/93	Alpena
BZGHIP	Benzo(g,h,i)perylene	Chronic: 3×10^{-2} (i) Subchronic: 3×10^{-1} (j)	NA	NA	NA	03/01/93	M
BDCME	Bromodichloromethane	Chronic: 2×10^{-2} (i) Subchronic: 2×10^{-2} (j)	NA	NA	NA	12/07/93	Alpena
CTCL	Carbon Tetrachloride	Chronic: 7×10^{-4} (i) Subchronic: 7×10^{-3} (j)	NA	NA	NA	12/07/93	Alpena
CLBZ	Chlorobenzene	Chronic: 5×10^{-3} (b) Subchronic: 5×10^{-2} (b)	NA	Liver and kidney effects	UF = 10,000 MF = 1	10/15/93	M
CR	Chromium, Total (g)	Chronic: 1.4×10^{-2} (h) Subchronic: 1.4×10^{-2} (f)	NA	NA	NA	12/07/93	Alpena

Key:

ND = No Data
NA = Not Available
UF = Uncertainty Factor
MF = Modifying Factor

(a) Retrieved from IRIS, 1993.
(b) Retrieved from HEAST, Annual FY92. FY93 used for Alpena
(c) UFs and MFs are for chronic RfDs.
(d) Chronic RfD for pyrene was used.
(e) Subchronic RfD for pyrene was used.
(f) Chronic RfD for DDT was used.
(g) Subchronic RfD for DDT was used.
(h) RfD calculated from conversion of 1.3 mg/L drinking water standard.
(i) RfD equal to chronic RfD.
(j) Data for total chlordane used.
(k) The value for Cr+6 rather Cr+3 was used as a worst-case toxicity value.
(l) Data for 2,3,7,8-TCDD used per California EPA, 1992a.
(m) Oral RfD for TCE provided by California EPA, 1992c.

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Table 4-3 Toxicity Values: Potential Noncarcinogenic Effects
MIANG, Alpena CRTC, Alpena, Michigan

Inhalation

PARLABEL	Chemical	RfD (c) (mg/kg-day)	Confidence Level	Critical Effects	Uncertainty and Modifying Factors (d)	Date Checked (IRIS)	Project
CHRYSENE	Chrysene	Chronic: 3×10^{-2} (i) Subchronic: 3×10^{-1} (j)	NA	NA	NA	12/07/93	Alpena
CU	Copper	Chronic: 5.7×10^{-2} (h) Subchronic: 5.7×10^{-2} (f)	NA	NA	NA	12/07/93	Alpena
DNBP	Di-n-butyl Phthalate	Chronic: 1×10^{-1} (i) Subchronic: 1 (j)	NA	NA	NA	03/02/93	M
DBF	Dibenzofuran	ND	NA	NA	NA	12/07/93	Alpena
DBCME	Dibromochloromethane	Chronic: 2×10^{-2} (i) Subchronic: 2×10^{-1} (j)	NA	NA	NA	12/07/93	Alpena
DCBZ14	1,4-Dichlorobenzene	Chronic: 2×10^{-1} (b) Subchronic: 2×10^{-1} (b)	NA	Liver, kidney effects	UF = 100 MF = 1	12/07/93	Alpena
DCA12	1,2-Dichloroethane	ND	NA	NA	NA	10/15/93	M
EBZ	Ethylbenzene	Chronic: 2.9×10^{-1} (a)(c) Subchronic: 2.9×10^{-1} (b)	Low	Developmental toxicity	UF = 300 MF = 1	03/02/93	M
FLA	Fluoranthene	Chronic: 5.7×10^{-4} (h) Subchronic: 5.7×10^{-4} (f)	NA	NA	NA	03/02/93	M
INP123	Indeno(1,2,3-c,d)pyrene	Chronic: 3×10^{-2} (i) Subchronic: 3×10^{-1} (j)	NA	NA	NA	12/07/93	Alpena
PB	Lead	ND	NA	NA	NA	12/07/93	Alpena
MTNPH2	2-Methylnaphthalene	Chronic: 3×10^{-2} (i) Subchronic: 3×10^{-1} (j)	NA	NA	NA	12/07/93	Alpena
MEPH4	4-Methylphenol (p-Cresol)	Chronic: 5×10^{-3} (i) Subchronic: 5×10^{-2} (j)	NA	NA	NA	05/06/93	M

Key:

ND = No Data
NA = Not Available
UF = Uncertainty Factor
MF = Modifying Factor

(a) Retrieved from IRIS, 1993.
(b) Retrieved from HEAST, Annual FY92. FY93 used for Alpena
(c) UFs and MFs are for chronic RfDs.
(d) Chronic RfD for pyrene was used.
(e) Subchronic RfD for pyrene was used.
(f) Chronic RfD for DDT was used.
(g) Subchronic RfD for DDT was used.
(h) RfD calculated from conversion of 1.3 mg/L drinking water standard.
(i) RfD equal to chronic RfD.
(j) Data for total chlordane used.
(k) The value for Cr+6 rather Cr+3 was used as a worst-case toxicity value.
(l) Data for 2,3,7,8-TCDD used per California EPA, 1992a.
(m) Oral RfD for TCE provided by California EPA, 1992c.

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Table 4-3 Toxicity Values: Potential Noncarcinogenic Effects
MIANG, Alpena CRTC, Alpena, Michigan

Inhalation

PARLABEL	Chemical	RfD (c) (mg/kg-day)	Confidence Level	Critical Effects	Uncertainty and Modifying Factors (d)	Date Checked (IRIS)	Project
MTNCL	Methylene Chloride	Chronic: 9×10^{-1} (b) Subchronic: 9×10^{-1} (b)	NA	Liver, kidney toxicity	UF = 100 MF = 1	03/02/93	M
NI	Nickel	Chronic: 2.9×10^{-5} (h) Subchronic: 2.9×10^{-5} (f)	NA	NA	NA	04/02/93	M
PHAN	Phenanthrene	Chronic: 5.7×10^{-4} (h) Subchronic: 5.7×10^{-4} (f)	NA	NA	NA	12/07/93	Alpena
PYR	Pyrene	Chronic: 5.7×10^{-4} (h) Subchronic: 5.7×10^{-4} (f)	NA	NA	NA	03/02/93	M
SE	Selenium	Chronic: 5×10^{-3} (i) Subchronic: 5×10^{-3} (j)	NA	NA	NA	12/07/93	Alpena
STY	Styrene	Chronic: 1×10^{0} (a) Subchronic: 9×10^{-1} (b)(c)	Medium	CNS effects	UF = 30 MF = 1	12/07/93	Alpena
PCE	Tetrachloroethylene	Chronic: 1×10^{-2} (i) Subchronic: 1×10^{-1} (j)	NA	NA	NA	12/07/93	Alpena
TCE	Trichloroethylene	Chronic: 7.35×10^{-3} (i) Subchronic: 7.35×10^{-3} (j)	NA	NA	NA	12/07/93	Alpena
VC	Vinyl Chloride	ND	NA	NA	NA	12/07/93	Alpena
ZN	Zinc	Chronic: 2.3×10^{-1} (h) Subchronic: 2.3×10^{-1} (f)	NA	NA	NA	12/07/93	Alpena

Key:

ND = No Data
NA = Not Available
UF = Uncertainty Factor
MF = Modifying Factor

(a) Retrieved from IRIS, 1993.
(b) Retrieved from HEAST, Annual FY92. FY93 used for Alpena
(c) UFs and MFs are for chronic RfDs.
(d) Chronic RfD for pyrene was used.
(e) Subchronic RfD for pyrene was used.
(f) Chronic RfD for DDT was used.
(g) Subchronic RfD for DDT was used.
(h) RfD calculated from conversion of 1.3 mg/L drinking water standard.
(i) RfD equal to chronic RfD.
(j) Data for total chlordane used.
(k) The value for Cr+6 rather Cr+3 was used as a worst-case toxicity value.
(l) Data for 2,3,7,8-TCDD used per California EPA, 1992a.
(m) Oral RfD for TCE provided by California EPA, 1992c.

wp/t4-3.775-06/15/95

4.4.2.2 Carcinogenic Toxicity Values

In the first step of a carcinogenic toxicity assessment, EPA evaluates human and animal studies to determine the weight-of-evidence classification for carcinogenicity. EPA adjusts the weight-of-evidence classification upward or downward, based on other supporting carcinogenic evidence, such as metabolic and other pharmacokinetics studies, cell cultures or microorganisms studies, or structure-activity studies. Table 4-4 gives the EPA weight-of-evidence classification system for carcinogenicity. This system has been adapted from the system developed by the International Agency for Research on Cancer (IARC).

In the second step of a toxicity assessment, EPA assigns a toxicity value to a chemical that defines quantitatively the relationships between dose and response. This toxicity value is named the slope factor (SF). EPA typically calculates SFs for potential carcinogens with weight-of-classifications of A, B1, and B2. Estimation of SFs for chemicals in Class C by EPA proceeds on a case-by-case basis.

For carcinogens, EPA assumes that there is essentially no level of exposure to a chemical with carcinogenic effects that does not pose a finite probability of generating a carcinogenic response. Consequently, in evaluating cancer risks, a carcinogenic effect threshold cannot be estimated.

The SF is an upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime (e.g., risk per unit dose or risk per mg/kg-day). EPA uses mathematical models and procedures to extrapolate from carcinogenic responses observed at high doses to responses expected at low doses. After data are fit to the appropriate model, the upper 95th percent confidence limit of the slope of the resulting dose-response curve is calculated. This value is known as the SF and is an upper 95th percent confidence limit on the probability of a response per unit intake of a chemical over a lifetime.

Table 4-5 gives the carcinogenic toxicity values for the chemicals of potential concern which are classified as A, B1, B2, or C carcinogens. The table gives the oral and inhalation SFs for each chemical, the weight-of-evidence classification, the type of cancer caused by each chemical, and the source of the SF. SFs were obtained from EPA's IRIS as a first source. These SFs have been verified by the EPA Carcinogen Risk Assessment Verification Endeavor (CRAVE) workgroup. If an SF could not be retrieved from IRIS, the SF was obtained from the HEAST as a second source.

4.5 RISK CHARACTERIZATION

The final step of the baseline risk assessment process is risk characterization. In this step the toxicity and exposure assessments are integrated into quantitative and qualitative expressions of risk.

The potential risks associated with the chemicals of potential concern were assessed relative to the identified exposure scenarios. The carcinogenic risk to receptor populations was quantified by calculating the chemical-specific risk associated with the average lifetime dose of each contaminant. Carcinogenic risk is expressed as the following formula:

Table 4-4 EPA Weight-of-Evidence Classification System for Carcinogenicity

Group	Description
A	Human Carcinogen
B1 or B2	Probable Human Carcinogen B1 indicates that limited human data are available B2 indicates sufficient evidence in animals and inadequate or no evidence in humans
C	Possible Human Carcinogen
D	Not classifiable as to human carcinogenicity
E	Evidence of noncarcinogenicity for humans

$$\textit{Carcinogenic Risk} = \textit{Chronic Daily Intake (CDI)} \times \textit{Slope Factor}$$

1×10^{-6} was considered the maximum acceptable carcinogenic risk. The cancer risks were summed for each exposure pathway contributing to exposure of the same individual or subpopulation. Cancer risks from the various exposure pathways were assumed to be additive.

To determine the noncarcinogenic risk the Hazard Quotient (HQ) for each chemical of concern was calculated. The HQ is the ratio between the intake and reference dose and is expressed as follows:

$$HQ = \frac{\textit{Chronic Daily Intake}}{\textit{Chronic reference dose (RfD)}}$$

A ratio greater than one indicates there may be concern for potential noncancer effects. In accordance with EPA guidance, the HQ for each chemical is summed for each pathway, resulting in a pathway hazard index (HI). This approach is conservative since health effects from exposure to different chemicals may result from the chemical affect on different organ systems. The pathway HIs were then summed to determine a total exposure HI. The factors utilized for the reference dose and SFs were established by EPA, while the calculated risks were determined as dictated by procedures established in the Risk Assessment Guidance for Superfund-Volume I-Human Health (RAGS) (EPA, 1989b) and the Supplemental Guidance (EPA, 1991).

4.6 PHYSICAL AND CHEMICAL PROPERTIES

The relevant physical and chemical properties of the chemicals of concern identified in Section 4.4, and their fate and transport are identified in the following paragraphs. Sources for this information include IRIS, HEAST, and Fate and Exposure Data, Vol I, II, and III.

Arsenic – Arsenic is a naturally-occurring metalloid which may be present in the environment in a number of different valence states. It may be a constituent of both organic and inorganic compounds. Arsenic is widely used by industry as an alloying agent, in ore-concentrating processes, and as a pesticide.

Table 4-5 Toxicity Values: Potential Carcinogenic Effects
MIANG, Alpena CRTC, Alpena, Michigan

PARLABEL	Chemical	Slope Factor (SF) $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	Type of Cancer	Date Checked (IRIS)	Project
ORAL						
AS	Arsenic	1.8 (a)(c)	A	Skin, lung	12/07/93	Alpena
BZ	Benzene	2.9×10^{-2} (a)	A	Leukemia	12/07/93	Alpena
BZAA	Benzo(a)anthracene	7.3 (d)	B2	Liver and Lung (mouse)	12/07/93	Alpena
BZAP	Benzo(a)pyrene	7.3 (a)	B2	Fore stomach (rat, mouse)	12/07/93	Alpena
BZBF	Benzo(b)fluoranthene	7.3 (d)	B2	Lung, thorax, liver, skin (rat, mouse)	12/07/93	Alpena
BZKF	Benzo(k)fluoranthene	7.3 (d)	B2	Lung, thorax, liver, skin (rat, mouse)	12/07/93	Alpena
BDCME	Bromodichloromethane	6.2×10^{-2} (a)	B2	Kidney, large intestine tumors (rat); kidney, liver tumors (mouse)	12/07/93	Alpena
CTCL	Carbon Tetrachloride	1.3×10^{-1} (a)	B2	Hepatocellular carcinomas/hepatomas (hamster, mouse, rat)	12/07/93	Alpena
CR	Chromium, Total (g)	4.2×10^{-1} (e)	A (h)	NA	12/07/93	Alpena
CHRYSENE	Chrysene	7.3 (d)	B2	Liver, lung (rat, mouse)	12/07/93	Alpena
DBCME	Dibromochloromethane	8.4×10^{-2} (a)	C	Liver (mice)	12/07/93	Alpena
DCBZ14	1,4-Dichlorobenzene	2.4×10^{-2} (b)	C	Liver tumors (mouse)	12/07/93	Alpena
DCA12	1,2-Dichloroethane	9.1×10^{-2} (a)	B2	Hemangiosarcomas (rat)	10/15/93	M
INP123	Indeno(1,2,3-c,d)pyrene	7.3 (d)	B2	Skin (mouse)	12/07/93	Alpena

Key:

ND = No Data
NA = Not Available
UF = Uncertainty Factor
MF = Modifying Factor

(a) Retrieved from IRIS, 1993.
(b) Retrieved from HEAST, Annual FY92. FY93 used for Alpena
(c) UFs and MFs are for chronic RfDs.
(d) Chronic RfD for pyrene was used.
(e) Subchronic RfD for pyrene was used.
(f) Chronic RfD for DDT was used.
(g) Subchronic RfD for DDT was used.
(h) RfD calculated from conversion of 1.3 mg/L drinking water standard.
(i) RfD equal to chronic RfD.
(j) Data for total chlordane used.
(k) The value for Cr+6 rather Cr+3 was used as a worst-case toxicity value.
(l) Data for 2,3,7,8-TCDD used per California EPA, 1992a.
(m) Oral RfD for TCE provided by California EPA, 1992c.

wp/t4-5.775-06/15/95

Table 4-5 Toxicity Values: Potential Carcinogenic Effects
MIANG, Alpena CRTC, Alpena, Michigan

PARLABEL	Chemical	Slope Factor (SF) $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	Type of Cancer	Date Checked (IRIS)	Project
ORAL						
PB	Lead	ND	B2	Kidney (rat, mouse)	12/07/93	Alpena
MTNCL	Methylene Chloride	7.5×10^{-3} (a)	B2	Liver (mouse)	03/02/93	M
MEPH4	4-Methylphenol (p-Cresol)	ND	C	Skin papillomas (mouse)	05/06/93	M
NI	Nickel	There is inadequate evidence for carcinogenicity by the oral route (b).			04/02/93	M
PCE	Tetrachloroethene	5.1×10^{-2} (e)	B2	Liver (mouse)	12/07/93	Alpena
TCE	Trichloroethene	1.5×10^{-2} (e) (proposed)	B2	Liver (mouse)	12/07/93	Alpena
VC	Vinyl Chloride	1.9(b)	A	Lung (rat)	12/07/93	Alpena
INHALATION						
AS	Arsenic	15 (a)(c)	A	Lung, skin	12/07/93	Alpena
BZ	Benzene	2.9×10^{-2} (a)(i)	A	Leukemia	12/07-93	Alpena
BZAA	Benzo(a)anthrancene	7.3 (d)	B2	NA	12/07/93	Alpena
BZAP	Benzo(a)pyrene	7.3 (d)	B2	Respiratory tract (hamster)	12/07/03	Alpena
BZBF	Benzo(b)fluoranthene	7.3 (d)	B2	NA	12/07/93	Alpena
BZKF	Benzo(k)fluoranthene	7.3 (d)	B2	NA	12/07/93	Alpena
BDCME	Bromodichloromethane	6.2×10^{-2} (k)	B2 (j)	NA	12/07/93	Alpena
INHALATION						
CTCL	Carbon Tetrachloride	5.3×10^{-2} (a)(i)	B2	Carcinogenicity (rat, mouse, hamster)	12/07/93	Alpena

Key:

ND = No Data
NA = Not Available
UF = Uncertainty Factor
MF = Modifying Factor

(a) Retrieved from IRIS, 1993.
(b) Retrieved from HEAST, Annual FY92. FY93 used for Alpena
(c) UFs and MFs are for chronic RfDs.
(d) Chronic RfD for pyrene was used.
(e) Subchronic RfD for pyrene was used.
(f) Chronic RfD for DDT was used.
(g) Subchronic RfD for DDT was used.
(h) RfD calculated from conversion of 1.3 mg/L drinking water standard.
(i) RfD equal to chronic RfD.
(j) Data for total chlordane used.
(k) The value for Cr+6 rather Cr+3 was used as a worst-case toxicity value.
(l) Data for 2,3,7,8-TCDD used per California EPA, 1992a.
(m) Oral RfD for TCE provided by California EPA, 1992c.

wp/t4-5.775-06/15/95

Table 4-5 Toxicity Values: Potential Carcinogenic Effects MIANG, Alpena CRTC, Alpena, Michigan

PARLABEL	Chemical	Slope Factor (SF) $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	Type of Cancer	Date Checked (IRIS)	Project
CR	Chromium, Total (g)	4.2×10^{1} (a)(i)	A	Lung	12/07/93	Alpena
CHRYSENE	Chrysene	7.3 (d)	B2	NA	12/07/93	Alpena
DBCME	Dibromochloromethane	8.4×10^{-2} (k)	C (j)	NA	12/07/93	Alpena
DCBZ14	1,4-Dichlorobenzene	4.0×10^{-2} (e)	C (j)	NA	12/07/93	Alpena
DCA12	1,2-Dichloroethane	9.1×10^{-2} (a)(i)	B2	Circulatory system (rat)	10/15/93	M
INP123	Ideno(1,2,3-c,d)pyrene	7.3 (d)	B2	NA	12/07/93	Alpena
PB	Lead	ND	B2	NA	12/07/93	Alpena
MTLNCL	Methylene Chloride	1.6×10^{-3} (a)(i)	B2	Lung, liver (mouse)	03/02/93	M
MEPH4	4-Methyphenol (p-Cresol)	ND	C (j)	NA	05/06/93	M
NI	Nickel	8.4×10^{-1} (a)	A	Respiratory tract	04/02/93	M
PCE	Tetrachloroethene	1.8×10^{-3} (e)	B2	Leukemia, liver (rat, mouse)	12/07/93	Alpena
TCE	Trichloroethene	1.0×10^{-2} (e)	B2	Lung (mouse)	12/07/93	Alpena
VC	Vinyl Chloride	3.0×10^{-1} (b)	A	Liver (rat)	12/07/93	Alpena

Key:

ND = No Data
NA = Not Available
UF = Uncertainty Factor
MF = Modifying Factor

(a) Retrieved from IRIS, 1993.
(b) Retrieved from HEAST, Annual FY92. FY93 used for Alpena
(c) UFs and MFs are for chronic RfDs.
(d) Chronic RfD for pyrene was used.
(e) Subchronic RfD for pyrene was used.
(f) Chronic RfD for DDT was used.
(g) Subchronic RfD for DDT was used.
(h) RfD calculated from conversion of 1.3 mg/L drinking water standard.
(i) RfD equal to chronic RfD.
(j) Data for total chlordane used.
(k) The value for Cr+6 rather Cr+3 was used as a worst-case toxicity value.
(l) Data for 2,3,7,8-TCDD used per California EPA, 1992a.
(m) Oral RfD for TCE provided by California EPA, 1992c.

wp/t4-5.775-06/15/95

Arsenic is generally extremely mobile in aquatic environments, and cycles through air, water, and soils. Its precise fate in a particular environment depends upon the complex interactions of a number of factors, including oxidation potention (Eh); pH; the presence and concentrations of metal sulfide and sulfide ions, phosphorus minerals, and iron; temperature; salinity; and the distribution and composition of the biota. Of these factors, Eh and pH have been shown to be most critical. Sediments and soils often act as a sink for arsenic through its absorption onto clays, iron oxides, aluminum hydroxide, and organic materials.

Benzene – Benzene is a colorless, aromatic hydrocarbon with a characteristic odor. Benzene was widely used in the past as a solvent and as an octane-raising additive in gasoline. Presently, benzene is used primarily in the chemical industry as a starting or intermediate material for the synthesis of many other organic compounds.

Benzene has been shown to be mobile in the soil/groundwater system. It is relatively soluble in groundwater and may be transported through sandy soils and soils of low organic content. The amount of benzene sorbed onto soil increases with increasing organic content. Benzene is highly volatile, and volatilization in surficial soils is probably an important transport mechanism. However, sorption of benzene vapors onto soil particles may slow vapor-phase transport. Hydrolysis is not expected to be an important process for benzene degredation. Data on the biodegradation of benzene are inconclusive. There is some evidence of gradual biodegradation at low concentrations by aquatic organisms, but the compound is considered fairly resistant to biodegradation. The rate of biodegradation may be enhanced in the presence of other hydrocarbons.

Carbon Tetrachloride – Carbon tetrachloride (CCl_4) is a solvent with limited usage in the U.S. because it is a potent hepatotoxin (i.e., toxic to the liver). Currently CCl^4 is mostly used in the production of fluorocarbons, but it is also employed as a fumigant and an insecticide. CCl^4 is moderately mobile in soil and only slightly absorbed to sediment. Rapid evaporation from soil is expected, as is rapid volatilization from water.

Chromium – Chromium is a transition element, occurring in nature principally as the trivalent ion, although valence states ranging from -2 to +6 have been reported in the literature. Chromium exists in two oxidation states in aqueous systems: Cr(III) and Cr(VI). The hexavalent form, Cr(VI), is quite soluble, existing in solution as a complex anion, and is not sorbed to any significant degree by clays or hydrous metal oxides. It is, however, sorbed strongly to activated carbon. Cr(VI) is a moderately strong oxidizing agent and reacts with reducing materials to form trivalent chromium. The trivalent form, Cr(III), reacts with aqueous hydroxide ions to form insoluble chromium hydroxide [$Cr(OH)_3$]. Most of the hydroxide form precipitates to the benthic zone in natural waters directly or by sorption.

In aquatic systems, plants and polychaete worms appear to be the most sensitive groups tested. The toxicity of Cr(VI) to aquatic species appears to increase as pH and/or hardness decrease. Bioaccumulation has been found to vary among species; concentrations are normally highest at lower trophic levels and lowest with the top predators, indicating that biomagnification does not occur.

Copper – Copper is a reddish-colored metal widely used as a structural material when high electrical and thermal conductivity is required. Copper salts are used as fungicides and in ceramics and electroplating, and have a wide variety of other industrial uses. Copper is a complexing agent, coordination numbers 2 and 4.

1,2-Dichloroethane – 1,2-DCA is a clear, thick man-made liquid that is not found naturally in the environment. It is volatile at room temperature and has a pleasant odor and sweet taste. It is flammable and burns with a smoky flame. It is used primarily to make vinyl chloride and a number of other solvents. 1,2-DCA can be inhaled or ingested but usually is removed from the body within one or two days.

Releases to the atmosphere from industrial processes are the primary source to the environment. Releases to soils and/or waters partition rapidly to the atmosphere since volatilization is the primary transport process. Photooxidation is its primary fate. Hydrolysis and biodegradation do not appear to be important degredation processes. 1,2-DCA released to soils will volatilize but a good portion will percolate through soils to groundwater since sorption to soils is not strong. Thus, 1,2-DCA may be available for groundwater transport processes.

Lead – Elemental lead is heavy, ductile, and bluish-white in color. It is widely used in industry because of its softness, resistance to corrosion and radiation, and high density. Lead is also used as a paint pigment, in solders, and in storage batteries.

The concentration and mobility of lead is controlled primarily by sorption. The tendency for lead to form compiexes with naturally-occurring organic materials increases its adsorptive affinity for clays and other mineral surfaces. At low pH values, sorption and precipitation are not nearly as effective in removing lead from solution; therefore, lead is much more mobile in acidic waters than at higher pH values. In alkaline and circumneutral waters, removal of lead by sorption and precipitation may occur relatively quickly. Bioaccumulation may also be an important fate process.

Methylene Chloride – Methylene chloride is used as a solvent for cellulose acetate, as degreasing and cleaning fluids and as a solvent in food processing. It is a colorless liquid whose vapor is not flammable. When mixed with air it is not explosive.

Methylene chloride is highly mobile in soil/groundwater systems. In the environment, volatization is the major transport process for removal of methylene chloride from aquatic systems. In the atmosphere, methylene chloride oxidizes into carbon dioxide, carbon monoxide and phosgene. In addition, some methylene chloride undergoes photodissociation with some atmospheric methylene chloride returned to earth in precipitation: hydrolysis, sorption, bioaccumulation and biotransformation are not significant processes determining the fate of methylene chloride.

Tetrachloroethylene – PCE is a colorless liquid with a pleasant, ethereal odor. It is used in the synthesis of spiro compounds and as an aromatizing agent. PCE is ubiquitous in the environment and has been detected in treated drinking water, marine and rain water, food, human tissues, the atmosphere, and marine organisms.

In the environment, volatilization is the major transport process for PCE. Some bioaccumulation may occur, but there is no evidence of biomagnification. Photodissociation, oxidation, hydrolysis, biodegradation, and adsorption do not appear to be important processes in determining the fate of PCE in the environment.

Trichloroethylene – TCE is a halogenated organic compound very commonly used in industry, primarily as a solvent. Other uses include dry cleaning, fumigation, paint dilution, aerospace operations, and textile processing.

TCE is relatively mobile in the soil/groundwater system, particularly where soils have a low organic content. It is moderately soluble in water, but can be sorbed onto soils with sufficiently high organic content. Transport mechanisms include volatilization in near-surface soils and migration in groundwater. Most TCE applied to surface soils will volatilize. The persistence of TCE in soil/groundwater systems is not known, but in most cases it is assumed that TCE will persist for at least months to years. TCE can be biodegraded into cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and vinyl chloride.

4.7 SITE 1 – POL STORAGE AREA RISK ASSESSMENT

A baseline risk assessment was conducted for the Site 1 POL Storage Area to estimate the health risk for human receptors.

Section 4.7.1 identifies the chemicals of potential concern. Section 4.7.2 presents an exposure assessment for human receptors. The toxicity assessment for chemicals of potential concern was previously presented in Section 4.4. The risk characterization for carcinogenic and noncarcinogenic effects is presented in Section 4.7.4. Uncertainties in the human health assessment are discussed in Section 4.7.5.

Section 4.7.6 presents a summary of total carcinogenic risk and the total exposure HIs for on-site adults and children.

4.7.1 Identification of Chemicals of Potential Concern

Chemicals of potential concern at Site 1 were selected for soils, groundwater, surface water, and sediments through the process outlined in Section 4.2. The results of the selection process are presented in Section 4.7.1.1 through 4.7.1.4.

4.7.1.1 Selection of Chemicals of Potential Concern within the Soil

Tables 3-3 and 3-4 present a summary of the validated surface (0.6 m [0-2 ft]) and subsurface (greater than 0.6 m [2 ft]) soil data collected during the RI. The complete data set is included in Appendix L. Additionally, soil data from the SI performed in November 1992 was used in the database development and these data are included in Appendix O. Tables 4-6 and 4-7 present a summary of the range of detected concentrations, the number of detections, and the MDNR criteria used in the evaluation.

Table 4-6 Data Summary Table: Surface Soil, Site 1 - POL Area MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/kg)	Act 307* Cleanup Criteria (µg/kg)
Aromatic Volatiles (ppb)			
1,4-Dichlorobenzene	1 / 36	0.0170 - 0.0170	30
Ethylbenzene	1 / 12	0.2000 - 0.2000	1500
Styrene	1 / 12	0.0450 - 0.0450	24
Halogenated Volatiles (ppb)			
1,1,1-Trichloroethane	1 / 12	2.7000 - 2.7000	4000
Methylene chloride	4 / 12	5.0000 - 9.3000	92
Semivolatiles (ppb)			
bis(2-Ethylhexyl)phthalate	2 / 12	37.0000 - 42.0000	92000 (G)
Metals (ppb)			
Arsenic	3 / 10	550 - 660	5800
Chromium	6 / 10	2800 - 13300	18000
Copper	2 / 10	2200 - 10500	32000
Lead	10 / 10	410 - 7100	20000
Nickel	3 / 10	3050 - 12200	20000
Silver	1 / 10	520 - 520	1000
TPH (ppb)			
Total Petroleum Hydrocarbons	7 / 12	9500 - 30100	

* Refer to Table 4-1 for explanation of Act 307 footnotes.
NA - Not Available

Table 4-7 Data Summary Table: Subsurface Soil, Site 1 - POL Area MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (μg/kg)	Act 307* Cleanup Criteria (μg/kg)
Aromatic Volatiles (ppb)			
1,2-Dichlorobenzene	2 / 27	0.0790 - 3.8000	12000
1,2-Dimethylbenzene	1 / 13	1500.0000 - 1500.0000	5600
1,4-Dichlorobenzene	3 / 35	0.0600 - 2.6000	30
Chlorobenzene	2 / 13	0.3100 - 6200.0000	2600
Ethylbenzene	2 / 13	0.1400 - 7900.0000	1500
Styrene	3 / 13	0.0220 - 7800.0000	24
Halogenated Volatiles (ppb)			
1,1,1,2-Tetrachloroethane	1 / 13	0.2300 - 0.2300	26
1,1,1-Trichloroethane	2 / 13	1.4000 - 2.2000	4000
1,2-Dichloroethane	1 / 13	0.4300 - 0.4300	7.6
1,4-Dichlorobenzene	3 / 35	0.0600 - 2.6000	30
Dibromomethane	1 / 13	0.9500 - 0.9500	1500
Methylene chloride	4 / 9	4.7000 - 10.0000	92
Tetrachloroethene	1 / 13	0.6300 - 0.6300	14
Trichloroethene	1 / 13	0.6400 - 0.6400	44
Metals (ppb)			
Arsenic	2 / 9	510 - 710	5800
Chromium	9 / 9	1300 - 4700	18000
Lead	9 / 9	940 - 3000	21000
Nickel	2 / 9	4100 - 4700	20000
TPH (ppb)			
Total Petroleum Hydrocarbons	11 / 13	9500 - 2220000	

* Refer to Table 4-1 for explanation of Act 307 footnotes.
NA - Not Available

wp/t4-7.775-06/15/95

No chemicals were detected in the surface soil above Act 307 Type B cleanup criteria. Chlorobenzene, ethylbenzene, and styrene were detected in the subsurface soil at levels above Act 307 Type B cleanup criteria and are considered chemicals of potential concern.

4.7.1.2 Selection of Chemicals of Potential Concern Within the Shallow Aquifer

Table 3-6 presents a summary of the groundwater data collected at Site 1 during the RI. The complete data set is included in Appendix L. Table 4-8 presents a summary of the range of detected concentrations, the number of detections, and the MDNR criteria used in the evaluation.

The following chemicals were detected at concentrations above the Act 307 cleanup criteria:

- Benzene
- Styrene
- 1,4 Dichlorobenzene
- Antimony, dissolved
- Dibenzofuran
- Bromodichloromethane
- Dibromochloromethane.

The above chemicals have been selected as chemicals of potential concern.

4.7.1.3 Selection of Chemicals of Potential Concern within the Sediment

Table 3-5 presents a summary of the validated sediment data. The complete data set is included in Appendix L. Table 4-9 presents a summary of the range of detected concentrations and the number of detections. No MDNR criteria are available for sediment.

As an initial screening process, the data were compared to soil background levels. Duplicate sample results were averaged with the original sample results and the average value used as a single sample result. No chemicals of potential concern were identified.

4.7.1.4 Selection of Chemicals of Potential Concern within the Surface Water

No surface water data was obtained from Thunder Bay River. Well PIMW12 is located approximately 30 m (100 ft) from the Thunder Bay River. Table 3-6 includes a summary of PIMW12 data. The complete data set is included in Appendix L. The data indicate that chemicals of potential concern present in the groundwater have not migrated to PIMW12 and therefore have not reached the Thunder Bay River. No chemicals of concern were identified.

Table 4-8 Data Summary Table: Groundwater, Site 1 - POL Area MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/l)	Act 307* Cleanup Criteria (µg/l)
Aromatic Volatiles (µg/l)			
1,2-Dichlorobenzene	1 / 9	8.5 / 8.5	600
1,2-Dimethylbenzene	1 / 9	5.8 / 5.8	280{R}
1,3-Dichlorobenzene	2 / 9	0.74 / 2.5	600
1,3-Dimethylbenzene	3 / 3	0.19 / 61	280{R}
1,4-Dichlorobenzene	1 / 9	25 / 25	1.5
Benzene	5 / 9	0.09 / 13	1.2
Chlorobenzene	1 / 9	0.68 / 0.68	130
Ethylbenzene	3 / 9	0.12 / 56	74{R}
Methyl-t-Butyl Ether	1 / 9	2.1 / 2.1	230
Styrene	1 / 9	8.5 / 8.5	1.2
Toluene	3 / 9	0.14 / 0.29	790{R}
Halogenated Volatiles (µg/l)			
1,1,1-Trichloroethane	1 / 9	0.14 / 0.14	200
Bromodichloromethane	1 / 9	0.63 / 0.63	0.56
Chloroform	3 / 9	0.14 / 0.68	5.6
Dibromochloromethane	1 / 9	1.9 / 1.9	0.42
Methylene chloride	2 / 9	0.36 / 0.42	4.6
Low Con. Semivolatiles (µg/l)			
2,4-Dimethylphenol	2 / 9	0.6 / 2	350
2-Methylnaphthalene	1 / 9	4 / 4	ID
Acenaphthene	1 / 9	3 / 3	1200
Dibenzofuran	1 / 9	1 / 1	ID
Fluorene	1 / 9	1 / 1	840
Naphthalene	1 / 9	12 / 12	250
Phenol	1 / 9	1 / 1	4200

wp/t4-8.775-06/15/95

Table 4-8 Data Summary Table: Groundwater, Site 1 - POL Area
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/l)	Act 307* Cleanup Criteria (µg/l)
Metals (µg/l)[1]			
Antimony, Dissolved	2 / 9	39.2 / 39.2	16.9{S}
Arsenic	6 / 9	7.7 / 28.6	
Beryllium	1 / 9	3.1 / 3.1	
Cadmium	1 / 9	5.7 / 5.7	
Chromium	7 / 9	9.9 / 119	
Copper	6 / 9	5.1 / 88.9	
Copper, Dissolved	2 / 9	5.1 / 6.3	1000{R}
Lead	6 / 9	12.7 / 60.3	
Mercury	1 / 9	0.37 / 0.37	
Nickel	4 / 9	38.3 / 93.5	
Selenium, Dissolved	1 / 9	4.9 / 4.9	35{C}
Zinc	8 / 9	7.5 / 147	
Zinc, Dissolved	3 / 9	10.3 / 25	2300{C}

* Refer to Table 4-1 for explanation of Act 307 footnotes.
[1] Criteria is presented for dissolved metals only.

wp/t4-8.775-06/15/95

Table 4-9 Data Summary Table: Sediment, Site 1 - POL Area
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/kg)	Act 307 Criteria (µg/kg)
Halogenated Volatiles (ppb)			
1,1,1-Trichloroethane	2 / 4	2.13 / 3.3	10(1)
Metals (ppb)			
Arsenic	4 / 4	960 / 5800	5800(2)
Chromium	4 / 4	2800 / 14700	18000
Copper	3 / 4	2300 / 24000	32000
Lead	4 / 4	1200 / 4000	21000
Nickel	2 / 4	4600 / 11700	20000
Zinc	4 / 4	15300 / 30300	47000
TPH (ppb)			
Total Petroleum Hydrocarbons	5 / 5	41100 / 133000	NA

(1) Acceptable detection limit for soils.
(2) Type A default criteria for soils applied for metals
Not Available

4.7.1.5 Selection of Chemicals of Potential Concern within the On-Site Production Well Water

Table 3-25 presents a summary of the validated production well data collected during the RI. The complete data set is included in Appendix L. Table 4-10 presents the range of detected concentrations, the number of detections, and the MDNR criteria used in the evaluation. Data from PW1, PW2, and PW3 were used in the evaluation. PW1 is the primary production well, while PW2 is the standby well. PW3 is monitored but not used.

Carbon tetrachloride was detected above the Act 307 Type B clean up criteria and has been identified as a chemical of potential concern. Carbon tetrachloride was detected only in the shallow aquifer production well PW3 and not in the bedrock aquifer production wells currently being used.

4.7.2 Exposure Assessment

The purpose of the exposure assessment is to estimate the type and magnitude of human receptor exposure to chemicals of potential concern resulting from Site 1 activities. The following exposure assessment components are evaluated in this section:

- Characterization of the exposure setting (Section 4.7.2.1)
- Identification of exposure pathways/receptors (Section 4.7.2.2)
- Estimation of chemical concentrations at receptors (Section 4.7.2.3)
- Estimation of on-site child and adult intake values (Section 4.7.2.3).

4.7.2.1 Characterization of the Exposure Setting

Site 1 lies within a fenced area inside the Alpena CRTC (Figure 1-2). The site was the former POL storage area for the facility. The site is overlain by gravel. Areas adjacent to the site, encompassed within the fenced area, are grass covered. To the west, toward Thunder Bay River, the area becomes heavily forested with deciduous and coniferous trees.

The south branch of the Thunder Bay River lies approximately 46 m (150 ft) west of Site 1. This portion of the Thunder Bay River is used for recreational purposes by personnel and their families who train at the facility during two week training sessions held April through September.

Groundwater contained in the shallow aquifer beneath Site 1 is separated into two distinct zones: a perched zone and a deeper unconfined zone. A clay unit which exists between depths of 3 to 6 m (10 to 20 ft) bgs separates these two zones. The limestone bedrock was encountered at a depth of approximately 40 bgs. No clay layer was present in boring S1MW1 separating the shallow aquifer from the bedrock. Groundwater within the perched aquifer does flow west toward the Thunder Bay River. Contamination within the perched zone could eventually migrate and be discharged into the river. Individuals utilizing the river for recreational purposes could be exposed to future contamination. Groundwater flow within the

Table 4-10 Data Summary Table: Groundwater, Production Wells
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/l)	Act 307* Cleanup Criteria (µg/l)
Aromatic Volatiles (µg/l)			
1,3-Dimethylbenzene	1 / 1	0.028 / 0.028	280{R}
Ethylbenzene	1 / 3	0.092 / 0.092	74{R}
Halogenated Volatiles (µg/l)			
Carbon Tetrachloride	1 / 3	1.2 / 1.2	0.27
Chloroform	1 / 3	0.28 / 0.28	5.6
Methylene chloride	2 / 3	0.28 / 0.37	4.6
Low Con. Semivolatiles (µg/l)			
Diethyl phthalate	1 / 3	0.9 / 0.9	5200
Phenol	1 / 3	2 / 2	4200
Metals (µg/l)			
Arsenic	1 / 3	6.4 / 6.4	
Lead	1 / 3	2.7 / 2.7	
Zinc	3 / 3	15.7 / 111	
Zinc, Dissolved	3 / 3	8.6 / 112	2300{C}
TPH (µg/l)			
Total Petroleum Hydrocarbons	3 / 3	300 / 4000	NA

* Refer to Table 4-1 for explanation of Act 307 footnotes.
NA Not Available
1) Criteria is presented for dissolved metals only.

lower unconfined zone is toward the northwest and also toward the river. This lower zone of the shallow aquifer likely contains sufficient water to support domestic wells.

The drinking water supply for the facility consists of on-site production wells. PW3 is located down gradient of Site 1 and is screened in the shallow aquifer. This production well was shut down by the state of Michigan due to the occurrence of organic compounds. PW1, the primary production well, is located up gradient of Site 1 and is screened in the limestone aquifer.

No wells were placed in the limestone aquifer, consequently, the direction of groundwater flow in the limestone aquifer is unknown; therefore, the relationship between the three production wells, in relation to groundwater flow direction, is unknown. Off-site residential wells lie to the north, south, and east of the Alpena CRTC. All residential wells are completed in the limestone aquifer (drilling logs supplied by Alpena County Health Department).

4.7.2.2 Identification of Exposure Pathways/Receptors

The ANG holds the lease on the land until 2039; therefore, the current land-use has also been evaluated for future exposure. The ANG currently utilizes the Site 1 area to park large vehicles. A large storage building is also present on the site. No personnel are routinely stationed in the Site 1 area. The Alpena CRTC consists of approximately 75 full-time employees. During the months of April through September, training sessions are held. These sessions last for two weeks. The personnel in training are housed at the CRTC during this time period. Family members come during the weekends and use the recreational facilities at the CRTC. Facilities include a River Club, located on the south branch of Thunder Bay River where canoeing, fishing, swimming, etc. takes place.

Future residential land-use is deemed highly improbable due to the location of the land in a rural area with low growth. The most likely alternate future land-use is recreational use for hunting, fishing, and swimming.

The following potential current exposure pathways and receptors were identified:

- Incidental ingestion of contaminated soil by facility personnel
- Soil inhalation of VOCs released from soil by facility personnel
- Dermal contact with contaminated soils by facility personnel
- Incidental ingestion of contaminated surface water by adults and children while swimming or playing in Thunder Bay River
- Dermal absorption of chemicals from contaminated deep aquifer groundwater during domestic use by facility personnel and visitors
- Inhalation of airborne chemicals from deep aquifer groundwater during domestic use by facility personnel

- Ingestion of contaminated fish caught in Thunder Bay River by adults and children
- Dermal absorption of contaminated surface water by adults and children while playing in Thunder Bay River
- Ingestion of contaminated drinking water from facility deep aquifer production wells by full-time facility personnel and visitors
- Inhalation of airborne chemicals from groundwater during domestic use by off-site residents
- Ingestion of contaminated drinking water from bedrock wells by off-site residents.

The following exposure pathways and receptors have been evaluated under the future land-use scenario:

- Future incidental ingestion of contaminated soil by construction workers
- Future inhalation of VOCs released from soil by construction workers
- Future dermal contact with contaminated soils by construction workers
- Future ingestion of contaminated groundwater from down gradient shallow aquifer production wells by adults and children
- Future inhalation of airborne chemicals from domestic use of groundwater from down gradient shallow aquifer production wells by adults and children
- Future dermal absorption of chemicals from contaminated groundwater from down gradient shallow aquifer wells by adults and children
- Future inhalation of airborne chemicals from groundwater from existing deep aquifer production wells by adults and children
- Future ingestion of contaminated drinking water from existing deep aquifer production wells by adults and children
- Future dermal absorption of contaminated drinking water from existing deep aquifer production wells by adults and children
- Future ingestion of contaminated fish caught in Thunder Bay River by adults and children
- Future incidental ingestion of contaminated surface water by adults and children while playing or swimming in Thunder Bay River
- Future dermal absorption of contaminated surface water by adults and children

- Future inhalation of airborne chemicals from domestic use of groundwater by off-site residents

- Future ingestion of contaminated drinking water from bedrock wells by off-site residents.

Because no current chemicals of potential concern were identified in the surface soil 0 to 0.6 m (0 to 2 ft) at Site 1, the following potential current exposure pathways are considered incomplete and are eliminated from further consideration:

- Ingestion of contaminated soil

- Dermal contact with contaminated soil

- Soil inhalation.

Additionally, no chemicals of concern were identified at the GSI point representing worst case surface water concentrations, therefore, the following pathways have also been eliminated from further consideration:

- Incidental ingestion of contaminated surface water

- Dermal absorption of contaminated surface water

- Ingestion of contaminated fish from Thunder Bay River.

The shallow aquifer production well is not used by the facility; therefore, no complete current exposure pathway exists. No chemicals of concern were detected in the two deep aquifer production wells currently used by the facility. Consequently, the following additional current exposure pathways are considered incomplete and are eliminated from further consideration:

- Ingestion of contaminated drinking water from shallow production wells

- Ingestion of contaminated drinking water from currently used production wells

- Inhalation of airborne chemicals from currently used production wells during domestic use

- Dermal absorption of chemicals from currently used production wells.

Future potential pathways involving the existing production wells will be retained for consideration based on the occurrence of carbon tetrachloride in the shallow production well which is currently not used.

Based on the elimination of all incomplete pathways, Table 4-11 presents the current and future exposure pathways which are considered complete.

Table 4-11 Current and Future Exposure Pathways - Site 1
MIANG, Alpena CRTC, Alpena, Michigan

Receptor Population	Exposure Point	Exposure Pathway
Current Land-Use		
Adult and Child	off-site	Ingestion of contaminated drinking water from residential wells.
Adult and Child	off-site	Inhalation of airborne chemicals released from groundwater during domestic use.
Future Land-use		
Excavation Worker	on-site	Future incidental ingestion of contaminated soil.
Excavation Worker	on-site	Future dermal contact with contaminated soil.
Excavation Worker	on-site	Future inhalation of VOCs volatilized from soil.
Adult and Child	on-site	Future ingestion of contaminated fish from Thunderbay River.
Adult and Child	on-site	Future incidental ingestion of contaminated surface water from Thunderbay River.
Adult and Child	on-site	Future dermal absorption of contaminated surface water.
Adult and Child	on-site	Future ingestion of contaminated groundwater from shallow aquifer production wells.
Adult and Child	on-site	Future inhalation of airborne chemicals released from groundwater during domestic use of shallow aquifer wells.
Adult and Child	on-site	Future ingestion of contaminated drinking water from existing production wells.
Adult and Child	off-site	Future ingestion of contaminated drinking water from bedrock wells.

4.7.2.3 Estimation of Chemical Concentrations at Receptors

Current Exposure Concentrations

The 95 percent UCL of the arithmetic mean, as outlined in Section 4.3, was calculated as the chemical exposure concentration for the following receptor exposure points:

- Current ingestion of surface water
- Current fish ingestion
- Current dermal absorption of surface water.

Table 4-12 presents the calculated exposure concentrations for each pathway. Appendix P includes the data set used to calculate the 95 percent UCLs. No data currently exist for off-site residential well water; therefore, these pathways will be addressed qualitatively.

Future Exposure Concentrations

Future concentrations of chemicals of potential concern in groundwater and surface water were predicted using a two-dimensional MOC solute transport model for the following receptor points (Konikow, Bredehoeft, and Goode, 1989):

- Future on-site shallow aquifer well water
- Future Thunder Bay River surface water.

These concentrations are presented in Table 4-12. Details on the model are included in Appendix P. The model estimates the peak concentration of chemicals of concern entering the down gradient shallow aquifer production well (PW3) over time. The model also estimates the peak concentration of chemicals of concern entering the Thunder Bay River over time. For chemicals currently detected in the production well, the current concentration is used as the peak value.

4.7.2.4 <u>Estimation of On-Site Child and Adult Intake Values</u>

On-site child and adult chronic CDI for carcinogenic effects and subchronic noncarcinogenic effects were estimated for exposure pathways identified in Table 4-11. Tables 4-13 through 4-21 present the formulas and assumptions used to model current and future reasonable maximum exposure (RME) intake values for each identified exposure pathway. Standard default exposure factors were used to estimate intake where applicable; acceptable exposure factor references are listed for those standard default exposure factors. Reasonable assumptions were made to quantify site-specific exposure factors. Site-specific assumptions were necessary to estimate exposure frequencies for children. Children of visiting or full-time personnel may use the on-site facilities during the weekends. It was assumed that children would be present on-site 6 months per year for 8 days per month, for a total of 48 days per year. It was further assumed that these children would be present through the childhood years (0-15 years) for an exposure duration of 15 years. The exposure frequency of 48 days per year was also assumed to be applicable for recreational land-use. For the current on-site and future recreational land-use, it was assumed that the adult worked at the facility or recreational area 250 days/year and used the recreational facilities an additional 48 days per year.

Using the exposure intake models presented in Tables 4-13 through 4-21, current and future chemical intake values were estimated for the potential receptors previously identified. Table 4-22 present a summary of the exposure assessment for current and future land-use at Site 1. Detailed calculations are presented in Appendix P.

Table 4-12
Reasonable Maximum Exposure Concentrations - Site 1
MIANG, Alpena CRTC, Alpena, Michigan

Matrix	Compound	Units	Arithmetic Mean	N	Maximum Value	Minimum Value	95% UCL	Maximum Modeled Concentration	Year Max Occurs
GROUNDWATER	Benzene	ug/l	2.72	9	13	0.09	5.84	0.27	5
GROUNDWATER	Antimony, Dissolved	ug/l	22.32	9	39.2	17.5	28.25	1.4	20
GROUNDWATER	Bromodichloromethane	ug/l	0.26	9	0.78	0.2	0.38	0.009	5
GROUNDWATER	Dibromochloromethane	ug/l	0.37	9	2.1	0.15	0.77	0.026	4.8
GROUNDWATER	Dibenzofuran	ug/l	2.33	9	2.5	1	2.64	0.005	20
GROUNDWATER	1,4-Dichlorobenzene	ug/l	6.31	4	25	0.075	20.97	0.0015	18.4
GROUNDWATER	Styrene	ug/l	1.06	9	8.5	0.125	2.79	0.0026	20
GROUNDWATER	Carbon Tetrachloride	ug/l	0.52	3	1.2	0.175	1.51	1.2	0
SEDIMENT	Arsenic	mg/kg	3.29	4	5.8	0.96	5.63		
SEDIMENT	Copper	mg/kg	8.14	4	24	0.95	20.76		
SUBSOIL	Chlorobenzene	ug/kg	1034.70	6	6200	0.31	3116.32		
SUBSOIL	Ethylbenzene	ug/kg	1317.69	6	7900	0.14	3970.36		
SUBSOIL	Styrene	ug/kg	1301.23	6	7800	0.66	3920.23234		
SURFACE WATER	Benzene	ug/l						0.16	20
SURFACE WATER	Antimony, Dissolved	ug/l						0.009	20
SURFACE WATER	Bromodichloromethane	ug/l						0.023	18.5
SURFACE WATER	Dibromochloromethane	ug/l						0.0015	
SURFACE WATER	Dibenzofuran	ug/l						0.005	18.5
SURFACE WATER	1,4-Dichlorobenzene	ug/l						0.002	19.2
SURFACE WATER	Styrene	ug/l						6.5	18.7
SURFACE WATER	Carbon Tetrachloride	ug/l						0.01	20

If 95% UCL is greater than the maximum, then the maximum value is the reasonable maximum exposure concentration.

Table 4-13 Model for Estimating Future Chemical Intake by Adults and Children through Drinking Water Ingestion – Site 1
MIANG, Alpena CRTC, Alpena, Michigan

$$CDI\ (mg/Kg\text{-}day) = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

where:

CDI	=	Chronic Daily Intake (mg/kg-day), representing the reasonable maximum exposure (RME).
CW	=	Chemical Concentration in Groundwater (mg/ℓ).
IR	=	Drinking Water Ingestion Rate (ℓ/day).
EF	=	Exposure Frequency (days/year).
ED	=	Exposure Duration (years).
BW	=	Body Weight (kg).
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	On Site/Recreational Adult[1]	Child
Ingestion Rate (IR) (ℓ/day)	2	2[1]
Exposure Frequency (EF) (days/yr)[3]	298	48[3]
Exposure Duration (ED) (years)	25	15[3]
Body Weight (kg)	70	27[2]
Averaging Time (years) (noncarcinogenic)	25	15

Notes:
1) All values from U.S. Environmental Protection Agency, 1991.
2) U.S. Environmental Protection Agency, 1989a.
3) Site specific assumption – see Section 4.7.2.4.

Table 4-14 Model for Estimating Future Chemical Absorbed Dose by Adults and Children through Dermal Contact with Chemicals in Groundwater - Site 1 MIANG, Alpena CRTC, Alpena, Michigan

$$\textit{Absorbed Dose (mg/kg-day)} = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

where:

CW	=	Chemical Concentration in Water (mg/ℓ).
SA	=	Skin Surface Area Available for Contact (cm^2).
PC	=	Chemical-specific Dermal Permeability Constant (cm/hr) default 8.4×10^{-4}
ET	=	Exposure Time (hours/day).
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
CF	=	Volumetric Conversion Factor for Water (1 liter/1000 cm^3)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	On-Site/Recreational Adult[5]	Recreational Child[5]
Skin Surface Area (cm^2)	19,400[1]	13,300[1]
Dermal Permeability Constant (cm/hr)[5]	8×10^{-4} [2]	8.4×10^{-4} [2]
Exposure Time (hours/day)[2,3]	0.25[3]	0.25[3]
Exposure Frequency (days/yr)[4]	298	48
Exposure Duration (years)[4]	25	15
Body Weight (kg)[2]	70	27
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) U.S. Environmental Protection Agency, 1989b – Child is average for ages 6-18.
2) U.S. Environmental Protection Agency, 1989a.
3) Based on a 15 minute exposure.
4) Site-specific assumption
5) Chemical specific permeabilities were used where available (Environmental Protection Agency, 1992a) benzene 1×10^{-1}, antimony 1×10^{-3}, bromodichloromethane 5.8×10^{-3}, dibromochloromethane 1.2×10^{-2}, 1,4 dichlorobenzene 6.2×10^{-2}

Table 4-15 Model for Estimating Future Intake by Adults and Children through Ingestion of Surface Water while Swimming or Playing in Thunder Bay River - Site 1 MIANG, Alpena CRTC, Alpena, Michigan

$$CDI\ (mg/kg\text{-}day) = \frac{CW \times CR \times ET \times EF \times ED}{BW \times AT}$$

where:

CDI	=	Chronic Daily Intake (mg/kg-day), representing the RME.
CW	=	Chemical Concentration in Surface Water (mg/ℓ).
CR	=	Surface Water Contact Rate (ℓ/hour).
ET	=	Exposure Time (hours/day).
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Adult	Child
Surface Water Contact Rate (m/hr)	50[1]	50[1]
Exposure Time (hours/day)	2.6[2]	2.6[2]
Exposure Frequency (days/yr)	48[3]	48[3]
Exposure Duration, (years)	25[3]	15[3]
Body Weight, (kg)	70[1]	27[1]
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) U.S. Environmental Protection Agency, 1989b.
2) U.S. Environmental Protection Agency, 1989a.
3) Site specific assumption – Section 4.7.2.4.

Table 4-16 Model for Estimating Future Chemical Intake by Adults and Children through Consumption of Fish Caught in Thunder Bay River - Site 1 MIANG, Alpena CRTC, Alpena, Michigan

$$CDI\ (mg/kg\text{-}day) = \frac{CF \times IR \times FI \times EF \times ED}{BW \times AT}$$

where:

CDI	=	Chronic Daily Intake (mg/kg-day), representing the RME.
IR	=	Ingestion rate (kg/day)
FI	=	The Fraction of total Figh Ingested which is caught from Thunderbay River (unitless).
EF	=	Exposure Frequency (days/year)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Adult	Child
Chemical Concentration in Fish[5]		
Ingestion Rate (kg/day)	0.054[1]	0.043[2]
Fraction of fish ingested (unitless)	0.50[3]	0.50[3]
Exposure Frequency (days/yr)	26[3]	26[3]
Exposure Duration (year)	25[1]	15[3]
Body Weight (kg)	70[1]	27[4]
Average Time (years), (noncarcinogenic)	25	15

Notes:
1) U.S. EPA, 1991.
2) Pao, Eleonore, M., 1982.
3) Site specific assumption, EF = 1 day/wk for 26 weeks.
4) U.S. EPA, 1989a.
5) Chemical concentration in fish is equal to the chemical concentration in surface water x fish bioconcentration factor (BCF). The following BCFs were applied: benzene 2.4×10^1 (MEPAS); Antimony 1 (Napier), Bromodichloromethane 30 (MEPAS), Dibromochloromethane 23 (MEPAS), Dibenzofuran 1 (default) 1.4 dichlorobenzene 60 (Environmental Protection Agency, 1980a), Styrene 100 (MEPAS), Carbon tetrachloride 17 (Environmental Protection Agency, 1980c), chromium 20 (Napier), Zinc 2000 (Napier).

Table 4-17 Model for Estimating Future Chemical Intake by Adults through Soil Ingestion- Site 1
MIANG, Alpena CRTC, Alpena, Michigan

$$Intake\ (mg/kg\text{-}day) = \frac{CS \times IR \times CF \times FI \times EF \times ED}{BW \times AT}$$

where:

CS	=	Chemical Concentration in Soil (mg/kg)
IR	=	Ingestion rate (mg/day)
CF	=	Conversion Factor (10^{-6} kg/mg)
FI	=	Fraction Ingested from Contaminated Source (unitless)
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Construction Worker[1]
Ingestion Rate (IR) (mg/day)	480
Fraction Ingested	1
Exposure Frequency (days/yr)	250
Age Group (year)	16-65
Exposure Duration (years)	0.08[2]
Body Weight (kg)	70
Averaging Time (years), (noncarcinogenic)	0.08

Notes:
1) All values from U.S. EPA, 1991.
2) Assumes excavation occurs for 1 month.

Table 4-18 Model for Estimating Future Chemical Absorbed Dose by Adults through Dermal Contact with Soils - Site 1
MIANG, Alpena CRTC, Alpena Michigan

$$Absorbed\ Dose\ (mg/kg\text{-}day) = \frac{CS \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

where:

CS	=	Chemical Concentration in Soil (mg/kg)
CF	=	Conversion Factor (10^{-6} kg/mg)
SA	=	Skin Surface Area Available for Contact (cm^2/event)
AF	=	Soil to Skin Adherence Factor (mg/cm^2)
ABS	=	Absorption Factor (unitless)
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Construction Worker
Surface area (cm^2/day)	3,120[1]
Soil to Skin Adherence Factor (mg/cm^2)	2.77
Absorption Factor	0.01 metals 0.25 organics
Exposure Frequency (days/yr)	250[3]
Exposure Duration (years)	0.08
Body Weight (kg)	70[3]
Averaging Time (year), (noncarcinogenic)	0.08

Notes:
1) U.S. Environmental Protection Agency, 1989b - Total of arms and hands
2) Excavation occurs for 1 month
3) U.S. Environmental Protection Agency, 1991.

Table 4-19 Model for Estimating Future Intake by Adults through Inhalation of Soil - Site 1 MIANG, Alpena CRTC, Alpena, Michigan

$$Intake\ (mg/kg\text{-}day) = \frac{CS\ x\ IR\ x\ CF\ x\ FI\ x\ EF\ x\ ED}{BW\ x\ AT}$$

where:

CA	=	Contaminant Concentration in Air (mg/m^3)
IR	=	Inhalation Rate (m^3/hour)
ET	=	Exposure Time (hours/day)
EF	=	Exposure Frequency (days/year)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

$$C_{air,ij} = \frac{(1000)E_{ij}}{XMU}$$

(Baker, 1991)

where:

X	=	Width of soil pile
M	=	Mixing height
U	=	Wind speed
1000	=	Conversion units mg/g
C_{air}	=	Concentration in air mg/m^3
E_i	=	average emission rate g/sec

and

$$E_i = \frac{2p_iM_iW_L}{R_T}\sqrt{\frac{D_iL_LU}{\Pi F_V}}$$

(Farmer, 1978)

P_i	=	Vapor pressure of pure component
M_i	=	Molecular weight g/mole
W_L	=	Width of open landfill, cm
R	=	gas constant, 6.23 X 10^{4}mm Hg-cm^3/mol-K
T	=	temperature
D_i	=	diffusivity of component i in air, cm^2/sec
F_V	=	Ficks Law conection factor dimensionless

Assumptions:	Construction Worker
Inhalation Rate (m^3/hr)	20
Exposure Time (hrs/day)^2	8
Exposure Frequency (days/yr)	250 days/yr
Exposure Duration (years)	0.08^2
Body Weight (kg)	70
Averaging Time (years)	
Carcinogens	70
Noncarcinogens	0.08

Notes:
1) All values from U.S. Environmental Protection Agency, 1991.
2) Assumes excavation activities are ongoing for 1 month

Table 4-20 Model for Estimating Future Chemical Intake by On-site Adults and Children through Inhalation of Vapor Phase Chemicals From Shallow Aquifer Groundwater – Site 1
MIANG, Alpena CRTC, Alpena, Michigan

$$Intake\ (mg/Kg\text{-}day) = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$$

where:

CA	=	Contaminant Concentration in Air (mg/m^3)
IR	=	Inhalation Rate (m^3/hour)
ET	=	Exposure Time (hours/day)
EF	=	Exposure Frequency (days/year)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:

$$CA\ (air\ contaminant\ concentration,\ mg/m^3) = \frac{(CA_{max}/2)t_1 + CA_{max}\ t_2}{t_1 + t_2}\ (1)$$

$$Where:\ CA_{max} = \frac{C_w f F_w t_1}{V_a}\ (1)$$

where:

C_w	=	The arithmetic mean or the 95% upper confidence limit (UCL) of the arithmetic mean of the contaminant concentration in shower water (mg/ℓ). Contaminant concentrations in groundwater which are used as shower water concentrations are presented in Table 4-12.
f	=	the fraction volatilized (unitless) is 0.7 (i.e., the mean of the range of 0.5 to 0.9) (Andelman, 1990).
F_w	=	The water flow rate (L/hr) is i.e., the mean of the range 500 to 1,000 ℓ/hr) (Wang, 1992).
t_1	=	The duration period for showering (hr) is 0.25 hr (California EPA, 1992a).
t_2	=	The duration period for the time after showering is 0.35 hr (i.e., the mean of the range of 0.2 to 0.5 hr) (Wang, 1992).
V_a	=	The bathroom volume (m^3) is 11 m^3 (i.e., the mean of the range of 6 to 16 m^3) (Wang, 1992).

(1) Reference: Wang, 1992.

	Facility Employee	Child
Inhalation Rate (m^3/hr)	0.6[1]	0.6[1]
Exposure Time (minutes)	7[1]	7[1]
Exposure Frequency (days/yr)	298[3]	48[3]
Exposure Duration (years)	25[2]	15
Body Weight (kg)	70[2]	27[4]
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) U.S. Environmental Protection Agency, 1989b.
2) U.S. Environmental Protection Agency, 1991.
3) Site specific assumption – see Section 4.7.2.4.
4) U.S. Environmental Protection Agency, 1989a.

Table 4-21 Model for Estimating Future Chemical Absorbed Dose by Adults and Children through Dermal Contact with Chemicals in Thunder Bay River - Site 1 MIANG, Alpena CRTC, Alpena, Michigan

$$Absorbed\ Dose\ (mg/kg\text{-}day) = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

where:

CW	=	Chemical Concentration in Water (mg/ℓ).
SA	=	Skin Surface Area Available for Contact (cm^2).
PC	=	Chemical-specific Dermal Permeability Constant (cm/hr) default 8.4×10^{-4}
ET	=	Exposure Time (hours/day).
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
CF	=	Volumetric Conversion Factor for Water (1 liter/1000 cm^3)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Recreational Adult	Facility Employee	Recreational Child
Skin Surface Area (cm^2)	19,400	19,400	13,300[1]
Dermal Permeability Constant (cm/hr)[4]	8.4×10^{-4}	8.4×10^{-4}	8.4×10^{-4} [2]
Exposure Time (hours/day)	2.6	2.6	2.6[2]
Exposure Frequency (days/yr)	48	48	48[3]
Exposure Duration (years)	25	25	15[3]
Body Weight (kg)	70	70	27[2]
Averaging Time (years), (noncarcinogenic)	25	25	15

Notes:
1) U.S. Environmental Protection Agency, 1989b – Child is average for ages 0-15.
2) U.S. Environmental Protection Agency, 1989a.
3) Site-specific assumption.
4) Chemical-specific permeability constants (Environmental Protection Agency, 1992) used where available. benzene 1×10^{1}, antimony 1×10^{-3}, bromodichloromethane 5.8×10^{-3}, dibromochloromethane 3.9×10^{-3}, 1,4 dichlorobenzene 6.2×10^{-2}, Carbon Tetrachloride 2.2×10^{-3}, Chromium 1×10^{-3}, Zinc 6×10^{-4}

Table 4-22
Exposure Assessment - Future Land Use - Site 1
MIANG, Alpena CRTC, Alpena, Michigan

Population	Exposure Pathway	Chemical	Chronic Daily Intakes (CDI) (mg/kg-day) Carcinogenic Effects	Chronic Daily Intakes (CDI) (mg/kg-day) Noncarcinogenic Effects	Subchronic Daily Intakes (SDI) (mg/kg-day) Noncarcinogenic Effects
On-Site/Recreational Adult	Ingestion of groundwater from production wells	Benzene	2.2E-06	6.3E-06	
		Antimony, Dissolved	1.2E-05	3.3E-05	
		Bromodichloromethane	7.5E-08	2.1E-07	
		Dibromochloromethane	2.2E-07	6.1E-07	
		Dibenzofuran	4.2E-08	1.2E-07	
		1,4-Dichlorobenzene	1.3E-08	3.5E-08	
		Styrene	2.2E-08	6.1E-08	
		Carbon Tetrachloride	10.0E-06	2.8E-05	
	Dermal contact with groundwater from production wells	Benzene	5.5E-07	1.5E-06	
		Antimony, Dissolved	2.8E-08	7.9E-08	
		Bromodichloromethane	1.1E-09	3.0E-09	
		Dibromochloromethane	2.0E-09	5.7E-09	
		Dibenzofuran	8.5E-11	2.4E-10	
		1,4-Dichlorobenzene	1.9E-09	5.3E-09	
		Styrene	4.4E-11	1.2E-10	
		Carbon Tetrachloride	5.3E-07	1.5E-06	
	Inhalation of vapor-phase chemicals released from groundwater during domestic use	Benzene	7.6E-07	2.1E-06	
		Antimony, Dissolved	0.0E+00	0.0E+00	
		Bromodichloromethane	2.6E-08	7.1E-08	
		Dibromochloromethane	7.4E-08	2.1E-07	
		Dibenzofuran	0.0E+00	0.0E+00	
		1,4-Dichlorobenzene	4.3E-09	1.2E-08	
		Styrene	7.4E-09	2.1E-08	
		Carbon Tetrachloride	3.4E-06	9.5E-06	
	Ingestion of surface water while swimming in Thunderbay River	Benzene	1.4E-08	3.9E-08	
		Antimony, Dissolved	7.9E-10	2.2E-09	
		Bromodichloromethane	2.0E-09	5.6E-09	
		Dibromochloromethane	1.3E-10	3.7E-10	
		Dibenzofuran	4.4E-10	1.2E-09	
		1,4-Dichlorobenzene	1.7E-10	4.9E-10	
		Styrene	5.8E-07	1.6E-06	
		Carbon Tetrachloride	8.7E-10	2.4E-09	
	Dermal contact with surface water from Thunderbay River	Benzene	5.4E-07	1.5E-06	
		Antimony, Dissolved	3.0E-10	8.5E-10	
		Bromodichloromethane	4.5E-09	1.3E-08	
		Dibromochloromethane	2.0E-10	5.5E-10	
		Dibenzofuran	1.4E-10	4.0E-10	
		1,4-Dichlorobenzene	4.2E-09	1.2E-08	
		Styrene	1.8E-07	5.2E-07	
		Carbon Tetrachloride	7.4E-09	2.1E-08	
	Consumption of fish from Thunderbay River	Benzene	3.8E-08	1.1E-07	
		Antimony, Dissolved	8.8E-11	2.5E-10	
		Bromodichloromethane	6.8E-09	1.9E-08	
		Dibromochloromethane	3.4E-10	9.5E-10	
		Dibenzofuran	4.9E-11	1.4E-10	
		1,4-Dichlorobenzene	1.2E-09	3.3E-09	
		Styrene	6.4E-06	1.8E-05	
		Carbon Tetrachloride	9.8E-11	2.7E-10	

Table 4-22 (continued)
Exposure Assessment - Future Land Use - Site 1
MIANG, Alpena CRTC, Alpena, Michigan

Population	Exposure Pathway	Chemical	Chronic Daily Intakes (CDI) (mg/kg-day) Carcinogenic Effects	Chronic Daily Intakes (CDI) (mg/kg-day) Noncarcinogenic Effects	Subchronic Daily Intakes (SDI) (mg/kg-day) Noncarcinogenic Effects
			1.7E-05		1.7E-05
Excavation Worker	Ingestion of soil during	Chlorobenzene	2.1E-05		2.1E-05
	construction activities	Ethylbenzene	2.1E-05		2.1E-05
		Styrene			
	Dermal contact with soil	Chlorobenzene	7.5E-08		6.6E-05
	during construction	Ethylbenzene	9.6E-08		8.4E-05
		Styrene	9.5E-08		8.3E-05
	Inhalation of vapor-phase chemicals	Chlorobenzene	9.2E-05		8.1E-02
	released from soil during	Ethylbenzene	7.0E-05		6.1E-02
	construction activities	Styrene	6.2E-05		5.4E-02
Recreational Child	Ingestion of groundwater	Benzene	5.6E-07	2.6E-06	
	from production wells	Antimony, Dissolved	2.9E-06	1.4E-05	
		Bromodichloromethane	1.9E-08	8.8E-08	
		Dibromochloromethane	5.4E-08	2.5E-07	
		Dibenzofuran	1.0E-08	4.9E-08	
		1,4-Dichlorobenzene	3.1E-09	1.5E-08	
		Styrene	5.4E-09	2.5E-08	
		Carbon Tetrachloride	2.5E-06	1.2E-05	
	Dermal contact with groundwater	Benzene	9.4E-08	4.4E-07	
	from production wells	Antimony, Dissolved	4.9E-09	2.3E-08	
		Bromodichloromethane	1.8E-10	8.5E-10	
		Dibromochloromethane	3.5E-10	1.6E-09	
		Dibenzofuran	1.5E-11	6.8E-11	
		1,4-Dichlorobenzene	3.2E-10	1.5E-09	
		Styrene	7.6E-12	3.5E-11	
		Carbon Tetrachloride	9.2E-08	4.3E-07	
	Inhalation of vapor-phase chemicals	Benzene	1.9E-07	8.9E-07	
	released from groundwater	Antimony, Dissolved	0.0E+00	0.0E+00	
	during domestic use	Bromodichloromethane	6.4E-09	3.0E-08	
		Dibromochloromethane	1.8E-08	8.6E-08	
		Dibenzofuran	0.0E+00	0.0E+00	
		1,4-Dichlorobenzene	1.1E-09	5.0E-09	
		Styrene	1.8E-09	8.6E-09	
		Carbon Tetrachloride	8.5E-07	4.0E-06	
	Ingestion of surface water while	Benzene	2.2E-08	1E-07	
	swimming in Thunderbay River	Antimony, Dissolved	1.2E-09	5.7E-09	
		Bromodichloromethane	3.1E-09	1.5E-08	
		Dibromochloromethane	2.0E-10	9.5E-10	
		Dibenzofuran	6.8E-10	3.2E-09	
		1,4-Dichlorobenzene	2.7E-10	1.3E-09	
		Styrene	8.8E-07	4.1E-06	
		Carbon Tetrachloride	1.4E-09	6.3E-09	
	Dermal contact with surface water	Benzene	5.8E-07	2.7E-06	
	from Thunderbay River	Antimony, Dissolved	3.2E-10	1.5E-09	
		Bromodichloromethane	4.8E-09	2.2E-08	
		Dibromochloromethane	2.1E-10	9.9E-10	
		Dibenzofuran	1.5E-10	7.1E-10	
		1,4-Dichlorobenzene	4.5E-09	2.1E-08	
		Styrene	2.0E-07	9.2E-07	
		Carbon Tetrachloride	7.9E-09	3.7E-08	

Table 4-22 (continued)
Exposure Assessment - Future Land Use - Site 1
MIANG, Alpena CRTC, Alpena, Michigan

Population	Exposure Pathway	Chemical	Chronic Daily Intakes (CDI) (mg/kg-day) Carcinogenic Effects	Chronic Daily Intakes (CDI) (mg/kg-day) Noncarcinogenic Effects	Subchronic Daily Intakes (SDI) (mg/kg-day) Noncarcinogenic Effects
Recreational Child	Consumption of fish from Thunderbay River	Benzene	4.7E-08	2.2E-07	
		Antimony, Dissolved	1.1E-10	5.1E-10	
		Bromodichloromethane	8.4E-09	3.9E-08	
		Dibromochloromethane	4.2E-10	2.0E-09	
		Dibenzofuran	6.1E-11	2.8E-10	
		1,4-Dichlorobenzene	1.5E-09	6.8E-09	
		Styrene	7.9E-06	3.7E-05	
		Carbon Tetrachloride	1.2E-10	5.7E-10	

4.7.3 Toxicity Assessments

Toxicity profiles for chemicals of potential concern were presented previously in Section 4.4.1, Toxicity Profiles. Section 4.4.2, Toxicity Values, presents the toxicity values for chemicals of potential concern.

4.7.4 Risk Characterization

The potential risks associated with the chemicals of concern were evaluated as outlined in Section 4.5. Section 4.7.4.1 presents the risk characterization for current land-use and Section 4.7.4.2 presents the future land-use risk characterization.

Current Land-Use Conditions

No current pathways were quantitatively evaluated. Potential exposure to off-site receptors is qualitatively evaluated in Section 4.7.6.

Future Land-Use Conditions

For future land-use conditions the on-site adult and child can be exposed to chemicals of concern through exposure to groundwater and surface water. As a worst case scenario, it was assumed that an on-site adult is exposed to groundwater contaminants while working at the facility during the work week and is exposed again through recreational activity on the weekends. Therefore, exposure pathways were summed for the adult and recreational child.

Exposure to soil contamination can only occur if the area is excavated since no surface soil contaminants were detected. The only receptor to soil exposure is the excavation worker. All soil exposure pathways were summed to provide a total exposure risk. No SFs exist for the contaminants of concern in soil; therefore, no cancer risks are presented for these pathways.

Tables 4-23 and 4-24 present cancer risk estimates for the future recreational child and on-site/recreational adult respectively. Detailed calculations are presented in Appendix P. Each table presents chemical-specific cancer risks, pathway cancer risks, and total-exposure cancer risk for the future on-site child and adult.

As indicated in the tables, no future cancer risks exceeding the 1×10^{-6} reference level are calculated for either the recreational child or the on-site/recreational adult for any surface water or groundwater pathways. The total risk for the on-site/recreational adult equals 1×10^{-6}. The risk attributable to ingestion of groundwater is equal to 1×10^{-6}, with approximately 95% of that risk attributable to carbon tetrachloride.

Chromium is the major contributor to the risk for these pathways. All other chemicals of concern have chemical-specific risks significantly below the acceptable level of 1×10^{-6}.

Table 4-23
Future Carcinogenic Risk Estimates for the Recreational Child - Site 1
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Ingestion of groundwater from production wells			
Benzene	2E-08		
Antimony, Dissolved	0E+00		
Bromodichloromethane	1E-09		
Dibromochloromethane	0E+00		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	8E-11		
Styrene	0E+00		
Carbon Tetrachloride	3E-07		
		3E-07	
Exposure Pathway: Dermal contact with groundwater from production wells			
Benzene	3E-09		
Antimony, Dissolved	0E+00		
Bromodichloromethane	1E-11		
Dibromochloromethane	0E+00		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	8E-12		
Styrene	0E+00		
Carbon Tetrachloride	1E-08		
		1E-08	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater during domestic use			
Benzene	6E-09		
Antimony, Dissolved	0E+00		
Bromodichloromethane	4E-10		
Dibromochloromethane	2E-09		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	4E-11		
Styrene	0E+00		
Carbon Tetrachloride	5E-08		
		5E-08	
Exposure Pathway: Ingestion of surface water while swimming in Thunderbay River			
Benzene	6E-10		
Antimony, Dissolved	0E+00		
Bromodichloromethane	2E-10		
Dibromochloromethane	0E+00		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	7E-12		
Styrene	0E+00		
Carbon Tetrachloride	2E-10		
		1E-09	

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Table 4-23 (continued)
Future Carcinogenic Risk Estimates for the Recreational Child - Site 1
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Dermal contact with surface water from Thunderbay River			
Benzene	2E-08		
Antimony, Dissolved	0E+00		
Bromodichloromethane	3E-10		
Dibromochloromethane	0E+00		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	1E-10		
Styrene	0E+00		
Carbon Tetrachloride	1E-09		
		2E-08	
Exposure Pathway: Consumption of Fish fromThunderbay River			
Benzene	1E-09		
Antimony, Dissolved	0E+00		
Bromodichloromethane	5E-10		
Dibromochloromethane	0E+00		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	4E-11		
Styrene	0E+00		
Carbon Tetrachloride	2E-11		
		2E-09	
Recreational Child - Total Future Cancer Risk			
			4E-07

Table 4- 24
Future Carcinogenic Risk Estimates for the On-Site/Recreational Adult - Site 1
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Ingestion of groundwater from production wells			
Benzene	7E-08		
Antimony, Dissolved	0E+00		
Bromodichloromethane	5E-09		
Dibromochloromethane	0E+00		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	3E-10		
Styrene	0E+00		
Carbon Tetrachloride	1E-06		
		1E-06	
Exposure Pathway: Dermal contact with groundwater from production wells			
Benzene	2E-08		
Antimony, Dissolved	0E+00		
Bromodichloromethane	7E-11		
Dibromochloromethane	0E+00		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	5E-11		
Styrene	0E+00		
Carbon Tetrachloride	7E-08		
		9E-08	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater during domestic use			
Benzene	2E-08		
Antimony, Dissolved	0E+00		
Bromodichloromethane	2E-09		
Dibromochloromethane	6E-09		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	2E-10		
Styrene	0E+00		
Carbon Tetrachloride	2E-07		
		2E-07	
Exposure Pathway: Ingestion of surface water while swimming in Thunderbay River			
Benzene	4E-10		
Antimony, Dissolved	0E+00		
Bromodichloromethane	1E-10		
Dibromochloromethane	0E+00		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	4E-12		
Styrene	0E+00		
Carbon Tetrachloride	1E-10		
		6E-10	

Table 4- 24 (continued)
Future Carcinogenic Risk Estimates for the On-Site/Recreational Adult - Site 1
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Dermal contact with surface water from Thunderbay River			
Benzene	2E-08		
Antimony, Dissolved	0E+00		
Bromodichloromethane	3E-10		
Dibromochloromethane	0E+00		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	1E-10		
Styrene	0E+00		
Carbon Tetrachloride	1E-09		
		2E-08	
Exposure Pathway: Consumption of Fish fromThunderbay River			
Benzene	1E-09		
Antimony, Dissolved	0E+00		
Bromodichloromethane	4E-10		
Dibromochloromethane	0E+00		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	3E-11		
Styrene	0E+00		
Carbon Tetrachloride	1E-11		
		2E-09	
On-Site / Recreational Adult - Total Cancer Risk			
			2E-06

Major Pathway Contributing to Risk	**Major Chemical Contributing to Pathway Risk**	**Chemical Percent Contribution**
Ingestion of Groundwater from Production wells	Carbon Tetrachloride	95

Tables 4-25 and 4-26 present chronic HI estimates for the future recreational child and on-site adult, respectively. Detailed calculations are presented in Appendix P. Subchronic HI estimates for the construction worker are also presented in Table 4-27. Each table presents chemical-specific hazard quotients, pathway HIs, and total exposure HIs for the on-site child and adult.

No future chronic HQs or HIs above the reference level of 1 are calculated for the recreational child and on-site/recreational adult. A subchronic HQ above the acceptable level of 1 was calculated for chlorobenzene for inhalation of VOCs released during excavation activities. A level above 1 indicates a high potential for adverse noncarcinogenic health effects.

4.7.5 Risk Assessment Uncertainties

This section presents a discussion of uncertainties involved in the process of quantifying risk for human receptors. Uncertainties involved in the exposure assessment, toxicity assessment, HI, and cancer risk estimation are discussed separately.

4.7.5.1 Exposure Assessment Uncertainties

Uncertainty in the exposure assessment is a function of the completeness of site data, assumptions that simplify and approximate actual current or future site conditions, and professional judgement used in developing and evaluating various parameters. Assumptions and inferences must be made to develop exposure scenarios. These assumptions and inferences introduce uncertainties into the exposure assessment.

The exposure scenarios presented are conservative and over-estimate, rather than under-estimate, exposure. The approach is conservative and is designed to compensate for uncertainties inherent in the exposure assessment. The use of very conservative health-protective exposure factors in the exposure assessment process results in final intake values that are extremely conservative.

In quantifying exposure levels, the chemicals are assumed to be uniformly distributed over the site, thus resulting in uniform exposure levels. Chemical analytical data were obtained from a directed sampling program, i.e., sampling locations were generally selected on the basis of where contaminants were expected to be present. This type of sampling scheme tends to greatly over-estimate the overall chemical concentrations at a site.

One of the assumptions used in the exposure assessment is that the future modeled chemical concentrations in wells are assumed to remain constant over exposure pathway duration and that the transport mechanisms are assumed to have reached equilibrium. This means that the levels will not decrease due to the exhaustion of the contaminant sources over the assumed exposure periods. The result of this assumption is an over-estimation of exposure point concentrations.

Table 4-25
Estimate of Future Noncarcinogenic Effects for the Recreational Child - Site 1
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of groundwater from production wells			
Benzene	0E+00		
Antimony, Dissolved	3E-02		
Bromodichloromethane	4E-06		
Dibromochloromethane	1E-05		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	0E+00		
Styrene	1E-07		
Carbon Tetrachloride	2E-02		
		5E-02	
Exposure Pathway: Dermal contact with groundwater from production wells			
Benzene	0E+00		
Antimony, Dissolved	1E-03		
Bromodichloromethane	4E-08		
Dibromochloromethane	8E-08		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	0E+00		
Styrene	4E-09		
Carbon Tetrachloride	1E-02		
		1E-02	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater during domestic use			
Benzene	0E+00		
Antimony, Dissolved	0E+00		
Bromodichloromethane	1E-06		
Dibromochloromethane	4E-06		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	2E-08		
Styrene	9E-09		
Carbon Tetrachloride	6E-03		
		6E-03	
Exposure Pathway: Ingestion of surface water while swimming in Thunderbay River			
Benzene	0E+00		
Antimony, Dissolved	1E-05		
Bromodichloromethane	7E-07		
Dibromochloromethane	5E-08		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	0E+00		
Styrene	2E-05		
Carbon Tetrachloride	9E-06		
		4E-05	

Table 4- 25 (continued)
Estimate of Future Noncarcinogenic Effects for the Recreational Child - Site 1
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal contact with surface water from Thunderbay River			
Benzene	0E+00		
Antimony, Dissolved	8E-05		
Bromodichloromethane	1E-06		
Dibromochloromethane	5E-08		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	0E+00		
Styrene	9E-05		
Carbon Tetrachloride	1E-03		
		1E-03	
Exposure Pathway: Consumption of Fish fromThunderbay River			
Benzene	0E+00		
Antimony, Dissolved	1E-06		
Bromodichloromethane	2E-06		
Dibromochloromethane	1E-07		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	0E+00		
Styrene	2E-04		
Carbon Tetrachloride	8E-07		
		2E-04	
Recreational Child - Total Future Hazard Index			
			7E-02

Table 4- 26
Estimate of Future Noncarcinogenic Effects for the On-Site / Recreational Adult - Site 1
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of groundwater from production wells			
Benzene	0E+00		
Antimony, Dissolved	8E-02		
Bromodichloromethane	1E-05		
Dibromochloromethane	6E-06		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	0E+00		
Styrene	3E-07		
Carbon Tetrachloride	4E-02		
		1E-01	
Exposure Pathway: Dermal contact with groundwater from production wells			
Benzene	0E+00		
Antimony, Dissolved	4E-03		
Bromodichloromethane	2E-07		
Dibromochloromethane	3E-07		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	0E+00		
Styrene	1E-08		
Carbon Tetrachloride	4E-02		
		5E-02	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater during domestic use			
Benzene	0E+00		
Antimony, Dissolved	0E+00		
Bromodichloromethane	4E-06		
Dibromochloromethane	1E-05		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	6E-08		
Styrene	2E-08		
Carbon Tetrachloride	1E-02		
		1E-02	
Exposure Pathway: Ingestion of surface water while swimming in Thunderbay River			
Benzene	0E+00		
Antimony, Dissolved	5E-06		
Bromodichloromethane	3E-07		
Dibromochloromethane	2E-08		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	0E+00		
Styrene	8E-06		
Carbon Tetrachloride	3E-06		
		2E-05	

Table 4- 26 (continued)
Estimate of Future Noncarcinogenic Effects for the On-Site / Recreational Adult - Site 1
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal contact with surface water from Thunderbay River			
Benzene	0E+00		
Antimony, Dissolved	4E-05		
Bromodichloromethane	6E-07		
Dibromochloromethane	3E-08		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	0E+00		
Styrene	5E-05		
Carbon Tetrachloride	6E-04		
		7E-04	
Exposure Pathway: Consumption of Fish fromThunderbay River			
Benzene	0E+00		
Antimony, Dissolved	6E-07		
Bromodichloromethane	9E-07		
Dibromochloromethane	5E-08		
Dibenzofuran	0E+00		
1,4-Dichlorobenzene	0E+00		
Styrene	9E-05		
Carbon Tetrachloride	4E-07		
		9E-05	
On-Site / Recreational Adult - Total Future Hazard Index			
			2E-01

Table 4-27
Future Hazard Quotient Index Risk Estimates for the Excavation Worker - Site 1
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of soil during construction activities			
Chlorobenzene	8E-05		
Ethylbenzene	2E-05		
Styrene	1E-04		
		2E-04	
Exposure Pathway: Dermal contact with soil during construction			
Chlorobenzene	7E-03		
Ethylbenzene	1E-03		
Styrene	8E-03		
		2E-02	
Exposure Pathway: Inhalation of vapor-phase chemicals released from soil during construction activities			
Chlorobenzene	2E+00		
Ethylbenzene	2E-01		
Styrene	6E-02		
		2E+00	
Excavation Worker - Total Future Hazard Index from Soil			
			2E+00

Major Pathway Contributing to Risk	**Major Chemical Contributing to Pathway Risk**	**Chemical Percent Contribution**
Inhalation of vapor phase chemicals	Chlorobenzene	86

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In evaluating the soil inhalation exposure pathway, it was assumed that the VOC emission rate remained constant and was equal to the emission rate for freshly excavated soil with no clean soil cap. This approach is conservative and may greatly over-estimate the concentration released to the air since the emission rate will decrease as subsequent soil layers lose their VOCs through progressively thicker soil caps.

Finally, the assumption is made that human exposure remains constant over the lifetime of an individual. In actuality, lifestyle changes due to age, and actual residence time will alter the projected exposure durations.

4.7.5.2 Toxicity Assessment

RfDs developed by the EPA are generally considered to have uncertainty spanning an order of magnitude or more. Consequently, total exposure HIs for the resident child and adult may be estimated high or low by an order of magnitude or more.

Low confidence by EPA in an RfD value, indicates high uncertainty in the accuracy of the toxicity value. High uncertainty indicates that the value may change in the future if additional toxicity data were to become available. Conversely, high confidence by the EPA in an RfD indicates low uncertainty in the accuracy of the toxicity value. SFs developed by the EPA are generally conservative and represent the upper bound limit of the probability of a cancer response. Thus, the actual cancer risk due to exposure to the chemicals of concern is likely to be lower than the estimated risk.

A second area of uncertainty is those chemicals which were not included in the quantitative assessment because of lack of carcinogenic or noncarcinogenic toxicity values. Chemicals lacking RfD values include benzene, dibenzofuran, and 1,4 dichlorobenzene, and those lacking SFs include chlorobenzene, ethylbenzene, antimony, dibromochloromethane, dibenzofuran, and styrene.

4.7.6 Conclusions

No complete pathways were identified for the current land-use scenario. Future pathways were evaluated for Site 1. A summary of the carcinogenic and noncarcinogenic risks was previously presented in Tables 4-23 through 4-27.

Per MDNR guidance, a cancer risk exceeding 1×10^{-6} is an unacceptable human health risk. Future carcinogenic risks equal to, but not exceeding, 1×10^{-6} are calculated for the on-site/recreational adult ingesting groundwater from the shallow aquifer production well (PW3). Carbon tetrachloride contributes approximately 95% of the risk. All other pathways are below the 1×10^{-6} reference level for the adult and child future land-use scenarios.

For noncarcinogenic effects, EPA guidance considers a HI greater than 1 to indicate potential for adverse noncarcinogenic health effects (EPA, 1989). It has been demonstrated that the future chronic HIs for the adult and child are below this reference level, indicating a low potential for adverse noncarcinogenic health effects.

A future subchronic HI above 1 is calculated for the excavation worker. The pathway responsible for the elevated HI is inhalation of VOCs during excavation. Chlorobenzene is the chemical responsible for this HI. An HI above 1 indicates a high potential for adverse noncarcinogenic health effects and in this case would indicate the possible need for personal protective equipment during excavation activities at the site.

Uncertainties in the health assessment were presented previously in Section 4.7.5. One area of uncertainty is the calculated inhalation intake for the calculation of VOC inhalation from soil during excavation activities. The model assumes a uniform concentration throughout the site, whereas in reality the VOCs detected in the soil are limited to one area of the site. Thus, while a noncarcinogenic risk may exist in one area of the site, it does not exist over the entire site.

No data was collected regarding the deeper aquifer. The potential for Site 1 contaminants to migrate into the deeper aquifer and contaminate on-site or off-site production wells is qualitatively assessed. Data collected during the RI indicate that the clay unit present between the perched and shallow aquifers is currently retarding the migration of Site 1 chemicals of concern, and no current risk to off-site receptors is apparent. Future risks to off-site receptors could occur if the contaminants migrate below the clay layer.

4.8 SITE 2 - MOTOR POOL AREA RISK ASSESSMENT

A baseline risk assessment was conducted for the Site 2 Motor Pool Area to estimate the health risk for human receptors.

Section 4.8.1 identifies the chemicals of potential concern. Section 4.8.2 presents an exposure assessment for human receptors. The toxicity assessment for chemicals of potential concern was previously presented in Section 4.4. The risk characterization for carcinogenic and noncarcinogenic effects is presented in Section 4.8.4. Uncertainties in the human health assessment are discussed in Section 4.8.5

Section 4.8.6 presents a summary of total carcinogenic risk and the total exposure HIs for on-site adult and child.

4.8.1 Identification of Chemicals of Potential Concern

Chemicals of potential concern at Site 2 were selected for soils and groundwater through the process outlined in Section 4.2. The results of the selection process are presented in Section 4.8.1.1 and 4.8.1.2

4.8.1.1 Selection of Chemicals of Potential Concern within the Soil

Tables 3-7 and 3-8 present a summary of the validated soil data collected during the RI. A complete data set is included in Appendix L. The soils data collected during the SI are included in Appendix O.

Tables 4-28 and 4-29 present a summary of the range of detected concentrations, the number of detections, and the MDNR criteria used in the evaluation. No chemicals were detected in the soil at Site 2 at levels above Act 307 Type B cleanup criteria. Elevated lead was detected in one soil sample up gradient from Site 2 and was rejected as a chemical of concern since it was not detected within Site 2 boundaries. No risk assessment will be performed for the soils at Site 2.

4.8.1.2 Identification of Chemicals of Potential Concern within the Shallow Aquifer

Table 3-9 presents a summary of the groundwater data collected at Site 2 during the RI. The complete data set is included in Appendix L. The previous three rounds of groundwater data are presented in appendices N and O. Table 4-30 presents a summary of the range of detected concentrations, the number of detections, and the MDNR criteria used in the evaluation.

The following chemicals were detected at levels above the Act 307 Type B cleanup criteria and have been selected as chemicals of potential concern:

- Tetrachloroethylene
- Arsenic, dissolved.

4.8.1.3 Identification of Chemicals of Potential Concern within the Surface Water

Groundwater from Site 2 discharges to the sinkhole, located at Site 4 over one half mile from Site 2. Identification of chemicals of potential concern associated with the sinkhole are addressed in Section 4.10, Site 4 Risk Assessment.

4.8.2 Exposure Assessment

The purpose of the exposure assessment is to estimate the type and magnitude of human receptor exposure to chemicals of potential concern resulting from Site 2 activities. The following exposure assessment components are evaluated in this section:

- Characterization of the exposure setting (Section 4.8.2.1)
- Identification of exposure pathways/receptors (Section 4.8.2.2)
- Estimation of chemical concentrations at receptors (Section 4.8.2.3)
- Estimation of on-site child and adult intake values (Section 4.8.2.4).

Table 4-28 Data Summary Table: Surface Soil, Site 2 - Motor Pool
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (μg/kg)	Act 307* Cleanup Criteria (μg/kg)
Halogenated Volatiles (ppb)			
Methylene chloride	1 / 4	17 / 17	92
Semivolatiles (ppb)			
Benzo(b)fluoranthene	1 / 4	52 / 52	180{G}
Benzo(k)fluoranthene	1 / 4	52 / 52	180{G}
Fluoranthene	1 / 4	51 / 51	17000
Pyrene	1 / 4	40 / 40	10000
bis(2-Ethylhexyl)phthalate	1 / 4	78 / 78	92000{G}
Metals (ppb)			
Arsenic	1 / 4	1100 / 1100	5800
Chromium	4 / 4	1900 / 10200	18000
Copper	3 / 4	3300 / 5100	32000
Lead	2 / 4	1300 / 31000	21000
Nickel	2 / 4	3700 / 8700	20000
Zinc	1 / 4	19200 / 19200	47000
TPH (ppb)			
Total Petroleum Hydrocarbons	4 / 4	12100 / 2520000	NA

* Refer to Table 4-1 for explanation of Act 307 footnotes.
NA - Not Available

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Table 4-29 Data Summary Table: Subsurface Soil, Site 2 - Motor Pool MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/kg)	Act 307* Cleanup Criteria (µg/kg)
Aromatic Volatiles (ppb)			
1,2-Dichlorobenzene	2 / 17	0.032 / 2.5	12000
1,2-Dimethylbenzene	2 / 17	0.11 / 0.12	5600
Styrene	1 / 17	0.036 / 0.036	24
Toluene	1 / 17	0.17 / 0.17	16000
Halogenated Volatiles (ppb)			
1,1,1-Trichloroethane	2 / 17	0.087 / 0.19	4000
Metals (ppb)			
Arsenic	1 / 17	750 / 750	5800
Chromium	17 / 17	1300 / 5100	18000
Copper	11 / 17	1500 / 2400	32000
Lead	11 / 17	820 / 6000	21000
Nickel	7 / 17	3900 / 6900	20000
Selenium	1 / 17	330 / 330	410
Zinc	2 / 17	12700 / 15300	47000
TPH (ppb)			
Total Petroleum Hydrocarbons	17 / 17	9400 / 193000	NA

* Refer to Table 4-1 for explanation of Act 307 footnotes.
NA - Not Available.

Table 4-30 Data Summary Table: Groundwater, Site 2 - Motor Pool
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/l)	Act 307* Cleanup Criteria (µg/l)
Aromatic Volatiles (µg/l)			
1,3-Dimethylbenzene	1 / 1	0.055 / 0.055	280{R}
Toluene	2 / 8	0.15 / 0.18	790{R}
Halogenated Volatiles (µg/l)			
Chloroform	1 / 8	0.18 / 0.18	5.6
Methylene chloride	3 / 8	0.052 / 0.4	4.6
Tetrachloroethylene	1 / 8	6.3 / 6.3	0.7
Trichloroethylene	1 / 8	0.36 / 0.36	2.2
Low Con. Semivolatiles (µg/l)			
Di-n-butyl phthalate	1 / 8	0.5 / 0.5	840
Diethyl phthalate	5 / 8	1 / 3	5200
Dimethyl phthalate	1 / 8	0.6 / 0.6	70000
Phenol	2 / 8	0.9 / 3	4200
Metals (µg/l)			
Arsenic	2 / 8	4 / 14.7	
Arsenic, Dissolved	1 / 8	7.2 / 7.2	1.85{S}
Copper	1 / 8	27.8 / 27.8	
Copper, Dissolved	1 / 8	5.7 / 5.7	1000{R}
Lead	1 / 8	4.5 / 4.5	
Silver	1 / 8	5.4 / 5.4	
Zinc	6 / 8	23.8 / 254	
Zinc, Dissolved	4 / 8	4.1 / 19.1	2300{C}
TPH (µg/l)			
Total Petroleum Hydrocarbons	1 / 8	400 / 400	

* Refer to Table 4-1 for explanation of Act 307 footnotes.
1) Criteria is presented for dissolved metals only.

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4.8.2.1 Characterization of the Exposure Setting

Site 2, Motor Pool Area, is located within the Alpena CRTC (Figure 1-5). Fencing that surrounds the site limits access to the area. The area of Site 2 inside the fence (north and west of Buildings 7 and 13) is asphalt covered, with adjacent areas covered in grass. The south branch of the Thunder Bay River lies approximately 305 m (1,000 ft) northwest of the site. A drainage ditch located west of Site 2 receives surface water runoff from the asphalt-covered portion of the site and received drainage from the site in previous years. This ditch is included in the source removal planned for Alpena CRTC and is not considered further here.

Shallow groundwater is present at depths ranging from 1.8 to 2.4 m (6 to 8 ft) bgs and flows north to northwest toward the sinkhole. A clay layer is present beneath the shallow aquifer. The limestone bedrock is present at approximately 17.7 m (58 ft) bgs. The shallow aquifer is approximately 15.2 m (50 ft) thick beneath Site 2. The aquifer likely contains sufficient water to support domestic wells.

The water supply for the Alpena CRTC consists of on site production wells. PW2 is located directly down gradient (based on shallow groundwater flow) of Site 2. This production well is normally on standby. This well is screened in both the shallow and deep aquifers and consequently, provides a potential conduit for contaminant migration from the shallow aquifer to the deeper aquifer. PW1, screened in the deeper aquifer only, is located further north of PW2. This well is the main water supply well for the facility.

The direction of groundwater flow in the limestone aquifer is not known at this time. Off-site residential wells lie to the north, south, and east of the Alpena CRTC. All residential wells are completed in the limestone aquifer (drilling logs supplied by Alpena County Health Department).

4.8.2.2 Identification of Exposure Pathways/Receptors

The ANG holds the lease on the land until 2039; therefore, the current land-use has also been evaluated for future exposure. Several employees are located full-time at the site. No recreational activities occur at or around the site since access is restricted. The site is asphalt covered, consequently, no current potential exists for exposure to surface soils. The south branch of Thunder Bay River, the closest surface water body, is not impacted by Site 2. The major portion of groundwater beneath Site 2 will eventually discharge at the sinkhole. The sinkhole is not currently used by training personnel or their families for recreational purposes. Based on groundwater elevations, any groundwater component from Site 2 toward the river would flow beneath the perched aquifer zone (which discharges into the river) and would have no impact on the river.

Residential land-use is deemed highly improbable due to the location of the land in a rural area with low growth. The most likely alternate future land-use is recreational use such as summer cabins, camping, etc).

The following potential current exposure pathways and receptors were identified:

- Ingestion of contaminated drinking water by facility personnel or visitors
- Inhalation of airborne chemicals from groundwater during use by facility personnel or visitors
- Dermal absorption of contaminated groundwater during use by facility personnel or visitors
- Ingestion of contaminated drinking water from limestone aquifer wells by off-site residents.

The above pathways were also evaluated for the future land-use scenario, in addition to the following scenarios:

- Ingestion of contaminated drinking water from future shallow aquifer wells by on-site personnel or recreational users
- Inhalation of airborne chemicals from future shallow groundwater during use by on-site personnel or recreational users
- Future dermal absorption of contaminated shallow groundwater during use by on-site personnel or recreational users
- Future ingestion of contaminated fish caught in the sinkhole by children and adults
- Future incidental ingestion of contaminated surface water by adults and children while playing or swimming in the sinkhole
- Future dermal absorption of contaminated surface water by adults and children while playing in the sinkhole
- Future ingestion of contaminated drinking water from bedrock wells by off-site residents.

Receptors include on-site adults, recreational children, and recreational adults. Exposure scenarios which include the sinkhole as a pathway will be evaluated under the Site 4 risk assessment.

Because no chemicals of concern were identified in the soil at Site 2, there are no complete exposure pathways for soil. Since the sinkhole is not used recreationally by Alpena CRTC there are no current complete exposure pathways for surface water or sediment at Site 2. No data currently exist on off-site residential wells; therefore, the potential risk is evaluated qualitatively for off-site receptors.

All future exposure scenarios involving the sinkhole are addressed as part of the Site 4 risk assessment and are not repeated here. Future exposure pathways involving the shallow and bedrock aquifer are evaluated here.

Table 4-31 presents the complete exposure pathways which are evaluated as part of the Site 2 risk assessment.

4.8.2.3 Estimation of Chemical Concentrations at Receptors

No data currently exist on off-site residential groundwater; therefore, these pathways will be addressed qualitatively.

Future shallow aquifer groundwater concentrations are assumed to be equal to current groundwater concentrations. Ninety-five percent UCLs are presented in Table 4-32. Future concentrations of chemicals of potential concern which would migrate to PW2 (a conduit to the limestone aquifer) and surface water were predicted using a two-dimensional MOC solute transport. The model estimates the peak concentration occurring in the down gradient production well PW2 over time. The estimated peak concentration in PW2 was then assumed to be the concentration in the limestone bedrock aquifer. Calculated RME concentrations are presented in Table 4-32. Details of the model are included in Appendix Q. Pathways involving off-site residential groundwater will be addressed qualitatively.

4.8.2.4 Estimation of On-Site Child and Adult Intake Values

On-site child and adult CDI values for carcinogenic effects and subchronic noncarcinogenic effects were estimated for exposure pathways identified in Table 4-31. Tables 4-33 through 4-35 present the formulas and assumptions used to model current and future RME intake values for each identified exposure pathway. Standard default exposure factors were used to estimate intake where applicable; acceptable exposure factor references are listed for those standard default exposure factors. Reasonable assumptions were made to quantify site-specific exposure factors.

Site-specific assumptions were necessary to estimate exposure frequencies for children. Children of visiting or full-time employees may use the on-site facilities during the weekends. It was assumed that children would be present on-site 6 months per year for 8 days per month for a total of 48 days per year. It was further assumed that these children would be present through the childhood years (0-15 years) for an exposure duration of 15 years. These assumptions were considered valid for the recreational land-use also. For both the current land-use and recreational land-use, it was assumed that the adult would work at the facility or recreational area 250 days per year and would use the recreational facilities an additional 48 days per year. This provides a worst case scenario for the groundwater pathways.

Using the exposure intake models presented in Tables 4-33 through 4-35 future chemical intake values were estimated for the potential receptors previously identified. Table 4-36 presents a summary of the exposure assessment for future land-use at Site 2. Detailed calculations are presented in Appendix Q.

Table 4-31 Current and Future Exposure Pathways - Site 2
MIANG, Alpena CRTC, Alpena Michigan

Receptor Population	Exposure Point	Exposure Pathway
Current Land-use		
Adult and Child	off-site	Ingestion of contaminated groundwater from bedrock wells
Future Land-use		
Adult and Child	on-site	Ingestion of contaminated groundwater from future shallow wells or existing deep aquifer production wells
Adult and Child	on-site	Inhalation of airborne chemicals from use of future shallow wells or existing deep aquifer production wells
Adult and Child	on-site	Dermal absorption of contaminated groundwater from future shallow wells or existing deep aquifer production wells
Adult and Child	off-site	Ingestion of contaminated groundwater from bedrock wells

4.8.3 Toxicity Assessment

Toxicity profiles for chemicals of potential concern were presented previously in Section 4.4.1, Toxicity Profiles. Section 4.4.2, Toxicity Values, presents the toxicity values for chemicals of potential concern.

4.8.4 Risk Characterization

The potential risks associated with the chemicals of concern were evaluated as outlined in Section 4.5. No current potential risks exist at Site 2 since no pathways were complete. The risk characterization for future land-use is presented as follows:

<u>Future Land-Use Conditions</u>

Tables 4-37 and 4-38 present future cancer risk estimates for the recreational child and on-site adult respectively. Detailed calculations are presented in Appendix Q. Each table presents chemical-specific cancer risks, pathway cancer risks, and total exposure cancer risk for the recreational child and on-site adult.

Future exposure to contaminated shallow groundwater can occur only if future wells are placed in the shallow aquifer. Exposure to contaminated deep aquifer groundwater can occur if contaminants from Site 2 migrate to production well PW2.

Table 4-32
Reasonable Maximum Exposure Concentrations - Site 2
MIANG, Alpena CRTC, Alpena, MI

Matrix	Compound	Units	Arithmetic Mean	N	Maximum Value	Minimum Value	95 % UCL	Maximum Modeled Concentration	Year Maximum Occurs
GROUNDWATER	Arsenic, Dissolved	ug/l	2.87	6	7.20	2.00	4.61		
GROUNDWATER	Tetrachloroethylene	ug/l	1.03	7	6.30	0.15	2.74		
GROUNDWATER	Arsenic, Dissolved	ug/l						0.90	5
GROUNDWATER	Tetrachlorethylene	ug/l						0.01	10
SOIL	Lead	mg/kg	16.15	2	31.00	1.30	109.91		

If 95% UCL is greater than the maximum value, then the maximum value is the reasonable maximum exposure concentration.

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Table 4-33 Model for Estimating Future Chemical Intake by Adults and Children through Drinking Water Ingestion – Site 2 MIANG, Alpena CRTC, Alpena, Michigan

$$CDI\ (mg/Kg\text{-}day) = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

where:

CDI	=	Chronic Daily Intake (mg/kg-day), representing the reasonable maximum exposure (RME).
CW	=	Chemical Concentration in Groundwater (mg/L).
IR	=	Drinking Water Ingestion Rate (L/day).
EF	=	Exposure Frequency (days/year).
ED	=	Exposure Duration (years).
BW	=	Body Weight (kg).
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Facility Employee[1]	Child
Ingestion Rate (IR) (L/day)	2	2[2]
Exposure Frequency (EF) (days/yr)	298[3]	48[3]
Exposure Duration (ED) (years)	25	15[3]
Body Weight (kg)	70	27[2]
Averaging Time (years), (noncarcinogenic effects)	25	15

Notes:
1) All values from U.S. EPA, 1991.
2) U.S. EPA, 1989.
3) Site specific assumption – see Section 4.8.2.4.

Table 4-34 Model for Estimating Future Chemical Intake by Adults and Children through Inhalation of Vapor Phase Chemicals – Site 2
MIANG, Alpena CRTC, Alpena, Michigan

$$Intake\ (mg/Kg\text{-}day) = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$$

where:

CA	=	Contaminant Concentration in Air (mg/m^3)
IR	=	Inhalation Rate (m^3/hour)
ET	=	Exposure Time (hours/day)
EF	=	Exposure Frequency (days/year)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:

$$CA\ (air\ contaminant\ concentration,\ mg/m^3) = \frac{(CA_{max}/2)t_1 + CA_{max}\, t_2}{t_1+t_2}\ (1)$$

$$Where:\ CA_{max} = \frac{C_w f F_w t_1}{V_a}\ (1)$$

where:

C_w	=	The arithmetic mean or the 95% upper confidence limit (UCL) of the arithmetic mean of the contaminant concentration in shower water (mg/ℓ). Contamininant concentrations in groundwater which are used as shower water concentrations are presented in Table 3.2-9.
f	=	the fraction volatilized (unitless) is 0.7 (i.e., the mean of the range of 0.5 to 0.9) (Andelman, 1990).
F_w	=	The water flow rate (ℓ/hr) is i.e., the mean of the range 500 to 1,000 ℓ/hr) (Wang, 1992).
t_1	=	The duration period for showering (hr) is 0.25 hr (California EPA, 1992a).
t_2	=	The duration period for the time after showering is 0.35 hr (i.e., the mean of the range of 0.2 to 0.5 hr) (Wang, 1992).
V_a	=	The bathroom volume (m^3) is 11 m^3 (i.e., the mean of the range of 6 to 16 m^3) (Wang, 1992).

(1) Reference: Wang, 1992.

	Facility Employee	Child
Inhalation Rate (m^3/hr)	0.6[1]	0.6[1]
Exposure Time (minutes)	7[1]	7[1]
Exposure Frequency (days/yr)	298[2]	48[3]
Exposure Duration (years)	25[2]	15
Body Weight (kg)	70[2]	27[4]
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) U.S. Environmental Protection Agency, 1989b.
2) U.S. Environmental Protection Agency, 1991.
3) Site specific assumption – see Section 4.8.2.4.
4) U.S. Environmental Protection Agency, 1989a.

Table 4-35 Model for Estimating Future Chemical Absorbed Dose by Adults and Children through Dermal Contact with Chemicals in Groundwater - Site 2 MIANG, Alpena CRTC, Alpena, Michigan

$$\text{Absorbed Dose } (mg/kg\text{-}day) = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

where:

CW	=	Chemical Concentration in Water (mg/ℓ).
SA	=	Skin Surface Area Available for Contact (cm^2).
PC	=	Chemical-specific Dermal Permeability Constant (cm/hr) default 8.4×10^{-4}
ET	=	Exposure Time (hours/day).
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
CF	=	Volumetric Conversion Factor for Water (1 liter/1000 cm^3)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Adult	Child
Skin Surface Area (cm^2)	19,400[1]	13,300[1]
Dermal Permeability Constant (cm/hr)[5]	8.4×10^{-4} [2]	8.4×10^{-4} [2]
Exposure Time (hours/day)	0.25[4]	0.25[4]
Exposure Frequency (days/yr)	298[3]	48[3]
Exposure Duration (years)	25[3]	15[3]
Body Weight (kg)	70	27[2]
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) U.S. Environmental Protection Agency, 1989b – Child is average for ages 0-15.
2) U.S. Environmental Protection Agency, 1989a.
3) Site specific assumption – See Section 4.8.2.4.
4) 15 minute exposure
5) Chemical specific permeability constants were used when available (EPA, 92) Arsenic 1×10^{-3}, PCE 4×10^{-1}.

Table 4-36
Exposure Assessment - Future Land Use - Site 2
MIANG, Alpena CRTC, Alpena, Michigan

Population	Exposure Pathway	Chemical	Chronic Daily Intakes (CDI)(mg/kg-day) Carcinogenic Effects	Noncarcinogenic Effects
On-Site/Recreational Adult	Ingestion of groundwater	Arsenic, Dissolved	3.8E-05	1.1E-04
		Tetrachloroethylene	2.3E-05	6.4E-05
	Ingestion of groundwater from deep aquifer production wells	Arsenic, Dissolved	7.5E-06	2.1E-05
		Tetrachloroethylene	8.3E-08	2.3E-07
	Inhalation of vapor-phase chemicals released from shallow groundwater	Arsenic, Dissolved	0.0E+00	0.0E+00
		Tetrachloroethylene	7.8E-06	2.2E-05
	Inhalation of vapor-phase chemicals released from groundwater deep aquifer production wells	Arsenic, Dissolved	0.0E+00	0.0E+00
		Tetrachloroethylene	2.8E-08	7.9E-08
	Dermal contact with shallow groundwater	Arsenic, Dissolved	2.8E-07	7.8E-07
		Tetrachloroethylene	2.2E-05	6.2E-05
	Dermal contact with groundwater from deep aquifer production wells	Arsenic, Dissolved	1.8E-08	5.1E-08
		Tetrachloroethylene	8.1E-08	2.3E-07
Recreational Child	Ingestion of groundwater	Arsenic, Dissolved	9.6E-06	4.5E-05
		Tetrachloroethylene	5.7E-06	2.7E-05
	Ingestion of groundwater from deep aquifer production wells	Arsenic, Dissolved	1.9E-06	8.8E-06
		Tetrachloroethylene	2.1E-08	9.7E-08
	Inhalation of vapor-phase chemicals released from shallow groundwater	Arsenic, Dissolved	0.0E+00	0.0E+00
		Tetrachloroethylene	1.9E-06	9.1E-06
	Inhalation of vapor-phase chemicals released from groundwater deep aquifer production wells	Arsenic, Dissolved	0.0E+00	0.0E+00
		Tetrachloroethylene	7.1E-09	3.3E-08
	Dermal contact with shallow groundwater	Arsenic, Dissolved	4.8E-08	2.2E-07
		Tetrachloroethylene	3.8E-06	1.8E-05
	Dermal contact with groundwater from deep aquifer production wells	Arsenic, Dissolved	3.1E-09	1.5E-08
		Tetrachloroethylene	1.4E-08	6.5E-08

Table 4-37
Future Carcinogenic Risk Estimates for the Recreational Child - Site 2
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Ingestion of shallow groundwater.			
Arsenic, Dissolved	2E-05		
Tetrachloroethylene	3E-07		
		2E-05	
Exposure Pathway: Ingestion of groundwater from deep aquifer production wells.			
Arsenic, Dissolved	3E-06		
Tetrachloroethylene	1E-09		
		3E-06	
Exposure Pathway: Inhalation of vapor-phase chemicals released from shallow groundwater.			
Arsenic, Dissolved	0E+00		
Tetrachloroethylene	3E-09		
		3E-09	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater deep aquifer productio			
Arsenic, Dissolved	0E+00		
Tetrachloroethylene	1E-11		
		1E-11	
Exposure Pathway: Dermal contact with shallow groundwater.			
Arsenic, Dissolved	9E-08		
Tetrachloroethylene	2E-07		
		3E-07	
Exposure Pathway: Dermal contact with groundwater from deep aquifer production wells.			
Arsenic, Dissolved	6E-09		
Tetrachloroethylene	7E-10		
		7E-09	
Recreational Child - Total Cancer Risk			
			2E-05

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Table 4-38
Future Carcinogenic Risk Estimates for the On-Site/Recreational Adult - Site 2
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk		Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Ingestion of shallow groundwater.				
Arsenic, Dissolved	7E-05	0.98		
Tetrachloroethylene	1E-06	0.02		
			7E-05	
Exposure Pathway: Ingestion of groundwater from deep aquifer production wells.				
Arsenic, Dissolved	1E-05	1.00		
Tetrachloroethylene	4E-09	0.00		
			1E-05	
Exposure Pathway: Inhalation of vapor-phase chemicals released from shallow groundwater.				
Arsenic, Dissolved	0E+00			
Tetrachloroethylene	1E-08			
			1E-08	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater deep aquifer production wells.				
Arsenic, Dissolved	0E+00			
Tetrachloroethylene	5E-11			
			5E-11	
Exposure Pathway: Dermal contact with shallow groundwater.				
Arsenic, Dissolved	5E-07	0.32		
Tetrachloroethylene	1E-06	0.68		
			2E-06	
Exposure Pathway: Dermal contact with groundwater from deep aquifer production wells.				
Arsenic, Dissolved	3E-08			
Tetrachloroethylene	4E-09			
			4E-08	
On-Site/Recreational Adult - Total Cancer Risk				
				9E-05

Major Pathway Contributing to Risk	Major Chemical Contributing to Pathway Risk	Chemical Percent Contribution
Ingestion of Shallow Groundwater	Arsenic	98
	Tetrachloroethylene	2
Ingestion of Groundwater from Deep Aquifer Production Wells	Arsenic	100
Dermal Contact with Shallow Groundwater	Tetrachloroethylene	68

Future carcinogenic risks above the reference level of 1×10^{-6} are calculated for the recreational child for the following pathways:

- Ingestion of shallow groundwater - (exceeds reference level by an order of magnitude).

- Ingestion of groundwater from deep aquifer production wells - (exceeds reference level but is the same order of magnitude).

Arsenic is the chemical contributing the majority of the risk for both ingestion of shallow groundwater (98%) and ingestion from deep aquifer (99%).

For the future on-site/recreational adult, the following pathways exceed the 1×10^{-6} reference level:

- Ingestion of shallow groundwater - (exceeds reference level by an order of magnitude).

- Ingestion of groundwater from deep aquifer production wells - (exceeds reference level by an order of magnitude).

- Dermal contact with shallow groundwater - (exceeds reference level but is the same order of magnitude).

Arsenic contributes the majority of the risk for both ingestion of shallow groundwater (98%) and ingestion of groundwater from the deep aquifer (100%). Tetrachloroethylene contributes 68% of the risk from dermal contact.

Tables 4-39 and 4-40 present future HI estimates for the recreational child and on-site/recreational adult, respectively. Detailed calculations are presented in Appendix Q. Each table presents chemical-specific HQs, pathway HIs, and total exposure HIs for the recreational child and adult.

All chemical-specific and total pathway HIs for both the recreational and on-site/recreational adult are below the reference level of 1. Total exposure HI is also below the reference level for both receptors.

4.8.5 Risk Assessment Uncertainties

This section presents a discussion of uncertainties involved in the process of quantifying risk for human receptors. Uncertainties involved in the exposure assessment, toxicity assessment, and HI and cancer risk estimation are discussed separately.

4.8.5.1 Exposure Assessment Uncertainties

Uncertainty in the exposure assessment is a function of the completeness of site data, assumptions that simplify and approximate actual current or future site conditions, and

Table 4-39
Estimate of Future Noncarcinogenic Effects for the Recreational Child - Site 2
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of shallow groundwater.			
Arsenic, Dissolved	1E-01		
Tetrachloroethylene	3E-03		
		2E-01	
Exposure Pathway: Ingestion of groundwater from deep aquifer production wells.			
Arsenic, Dissolved	3E-02		
Tetrachloroethylene	1E-05		
		3E-02	
Exposure Pathway: Inhalation of vapor-phase chemicals released from shallow groundwater.			
Arsenic, Dissolved	0E+00		
Tetrachloroethylene	9E-04		
		9E-04	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater deep aquifer productio			
Arsenic, Dissolved	0E+00		
Tetrachloroethylene	3E-06		
		3E-06	
Exposure Pathway: Dermal contact with shallow groundwater.			
Arsenic, Dissolved	7E-04		
Tetrachloroethylene	2E-03		
		3E-03	
Exposure Pathway: Dermal contact with groundwater from deep aquifer production wells.			
Arsenic, Dissolved	5E-05		
Tetrachloroethylene	6E-06		
		6E-05	
Recreational Child - Total Hazard Index			
			2E-01

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Table 4-40
Estimate of Future Noncarcinogenic Effects for the On-Site/Recreational Adult - Site 2
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of shallow groundwater.			
Arsenic, Dissolved	4E-01		
Tetrachloroethylene	6E-03		
		4E-01	
Exposure Pathway: Ingestion of groundwater from deep aquifer production wells.			
Arsenic, Dissolved	7E-02		
Tetrachloroethylene	2E-05		
		7E-02	
Exposure Pathway: Inhalation of vapor-phase chemicals released from shallow groundwater.			
Arsenic, Dissolved	0E+00		
Tetrachloroethylene	2E-03		
		2E-03	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater deep aquifer production			
Arsenic, Dissolved	0E+00		
Tetrachloroethylene	8E-06		
		8E-06	
Exposure Pathway: Dermal contact with shallow groundwater.			
Arsenic, Dissolved	3E-03		
Tetrachloroethylene	6E-03		
		9E-03	
Exposure Pathway: Dermal contact with groundwater from deep aquifer production wells.			
Arsenic, Dissolved	2E-04		
Tetrachloroethylene	2E-05		
		2E-04	
OnSite/Recreational Adult - Total Hazard Index			
			4.46E-01

professional judgement used in developing and evaluating various parameters. Assumptions and inferences must be made to develop exposure scenarios. These assumptions and inferences introduce uncertainties into the exposure assessment.

The exposure scenarios presented are conservative and overestimate, rather than underestimate, exposure. The approach is conservative and is designed to compensate for uncertainties inherent in the exposure assessment. The use of very conservative health-protective exposure factors in the exposure assessment process results in final intake values that are extremely conservative.

In quantifying exposure levels, the chemicals are assumed to be uniformly distributed over the site, thus resulting in uniform exposure levels. Chemical analytical data were obtained from a directed sampling program, i.e., sampling locations were generally selected on the basis of where contaminants were expected to be present. This type of sampling scheme tends to greatly overestimate the overall chemical concentrations at a site.

One of the assumptions used in the exposure assessment is that the current and future modeled chemical concentrations in wells are assumed to remain constant over exposure pathway duration and that the transport mechanisms are assumed to have reached equilibrium. This means that the levels will not decrease due to the exhaustion of the contaminant sources over the assumed exposure periods. The result of this assumption is an overestimation of exposure point concentrations.

Finally, the assumption is made that human exposure remains constant over the lifetime of an individual. In actuality, lifestyle changes due to age and actual residence time will alter the projected exposure durations.

4.8.5.2 Toxicity Assessment

RfDs developed by the EPA are generally considered to have uncertainty spanning an order of magnitude or more. Consequently, total exposure HIs for the resident child and adult may be estimated high or low by an order of magnitude or more.

Low confidence by EPA in an RfD value, indicates high uncertainty in the accuracy of the toxicity value. High uncertainty indicates that the value may change in the future if additional toxicity data were to become available. Conversely, high confidence by the EPA in an RfD indicates low uncertainty in the accuracy of the toxicity value. SFs developed by the EPA are generally conservative and represent the upper bound limit of the probability of a cancer response. Thus, the actual cancer risk due to exposure to the chemicals of concern is likely to be lower than the estimated risk.

4.8.6 Conclusions

No current pathways were quantitatively evaluated for Site 2. A summary of future carcinogenic and noncarcinogenic risks was presented previously in Tables 4-37 through 4-40.

Per MDNR guidance a cancer risk exceeding 1×10^{-6} is an unacceptable human health risk. The total future cancer risk for the recreational child exceeds the 1×10^{-6} reference level. Specific pathways exceeding the acceptable level are future ingestion of shallow groundwater and future ingestion of groundwater from the bedrock aquifer production wells, based on migration of shallow aquifer contaminants to production well PW2. Arsenic is the only chemical with a chemical-specific risk above 1×10^{-6} for these two pathways.

Total cancer risk exceeding the 1×10^{-6} reference level is calculated for the future on-site/recreational adult. Specific pathways exceeding the acceptable level are future ingestion of shallow groundwater, dermal contact with shallow groundwater, and future ingestion of groundwater from the bedrock aquifer production wells. Arsenic is the only chemical with a chemical-specific risk above 1×10^{-6} for pathways, while PCE is above 1×10^{-6} for dermal contact pathway.

Uncertainties in the risk assessment were evaluated in Section 4.8.5. The largest uncertainty for the Site 2 health assessment is the assumption that current chemical concentrations detected in the monitoring wells remain constant over the exposure time. This assumption affects both the shallow groundwater scenarios and the deep aquifer groundwater scenarios. The risks for these two exposure points is likely overestimated.

No data were collected regarding the deeper limestone aquifer. The potential for migration of contaminants from the shallow aquifer into the lower bedrock aquifer is qualitatively assessed. A clay layer exists at Site 2 which may retard the direct migration of contaminants into the lower aquifer. The presence, however, of PW2 (screened in both the shallow and deep aquifers) down gradient from Site 2 provides a direct conduit for contaminants to migrate to the lower aquifer. This conduit is available regardless of whether the production well is in service. The groundwater model indicates that contaminants will migrate toward PW2 and that unacceptable exposure risks may occur.

4.9 SITE 3- FORMER COUNTY GARAGE RISK ASSESSMENT

A baseline risk assessment was conducted for Site 3, Former County Garage, to estimate the health risk for human receptors.

Section 4.9.1 identifies the chemicals of potential concern. Section 4.9.2 presents an exposure assessment for human receptors. The toxicity assessment for chemicals of potential concern was previously presented in Section 4.4. The risk characterization for carcinogenic and noncarcinogenic effects is presented in Section 4.9.4. Uncertainties in the human health assessment are discussed in Section 4.9.5.

Section 4.9.6 presents a summary of total carcinogenic risk and the total exposure HIs for on-site adults and children.

4.9.1 Identification of Chemicals of Potential Concern

Chemicals of potential concern at Site 3 were selected for soils and groundwater through the process outlined in Section 4.2. The results of the selection process are presented in Section 4.9.1.1 through 4.9.1.3.

4.9.1.1 Selection of Chemicals of Potential Concern within the Soil

Tables 3-10 and 3-11 present a summary of the validated surface (0 to 0.6 m [0 to 2 ft]) and subsurface soil data collected during the RI. The complete data set is included in Appendix L. The data collected previous to the RI is included in Appendix O but was not used to estimate risk because of the age of the data (collected in 1987), as recommended by MDNR.

Table 4-41 and 4-42 present a summary of the range of detected concentrations, the number of detections, and the MDNR criteria used in the evaluation.

The following chemicals were detected at levels above Act 307 Type B cleanup criteria and have been selected as chemicals of potential concern:

- Benzo (a) pyrene
- Dibenzofuran
- Phenanthrene.

4.9.1.2 Selection of Chemicals of Potential Concern within the Shallow Aquifer

Table 3-21 presents a summary of the validated groundwater data collected during the RI. The complete data set is included in Appendix L. Table 4-43 presents a summary of the range of detected concentrations, the number of detections, and the MDNR criteria used in the evaluation. Data collected previous to the RI is included in Appendix N and O but was not used to estimate risk.

No chemicals were detected above the Act 307 Type B cleanup criteria, consequently, no chemicals of potential concern were identified in the shallow aquifer.

4.9.1.3 Selection of Chemicals of Potential Concern in the Surface Water

Shallow groundwater from Site 3 discharges to the sinkhole at Site 4. There are no surface water bodies present on Site 3. Identification of chemicals of potential concern associated with the sinkhole are addressed in Section 4.10, Site 4 Risk Assessment.

Table 4-41 Data Summary Table: Surface Soil, Site 3-Former Site of County Garage
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations μg/kg	Act 307* Cleanup Criteria μg/kg
Aromatic Volatiles (ppb)			
1,2-Dichlorobenzene	1 / 4	0.07 / 0.07	12000
1,3-Dimethylbenzene	1 / 1	0.18 / 0.18	5600
1,4-Dichlorobenzene	1 / 4	0.15 / 0.15	30
Toluene	1 / 4	0.18 / 0.18	16000
Halogenated Volatiles (ppb)			
Methylene Chloride	1 / 4	4.2 / 4.2	92
Semivolatiles (ppb)			
Anthracene	1 / 4	76 / 76	140000
Benzo(a)anthracene	1 / 4	290 / 290	1800
Benzo(a)pyrene	1 / 4	170 / 170	180(G)
Benzo(b)fluoranthene	1 / 4	430 / 430	1800
Benzo(ghi)perylene	1 / 4	140 / 140	180(G)
Benzo(k)fluoranthene	1 / 4	430 / 430	18,000
Carbazole	1 / 4	60 / 60	
Chrysene	1 / 4	250 / 250	180,000
Fluoranthene	1 / 4	640 / 640	17000
Fluorene	1 / 4	39 / 39	17000
Indeno(1,2,3-c,d)pyrene	1 / 4	160 / 160	1800
Phenanthrene	1 / 4	440 / 440	500
Pyrene	1 / 4	420 / 420	10000
Metals (ppb)			
Arsenic	2 / 4	600 / 1500	5800
Chromium	4 / 4	2400 / 7000	18000
Copper	2 / 4	190 / 6600	32000
Lead	4 / 4	2100 / 13500	21000
Nickel	1 / 9	3700 / 3700	21000
TPH (ppb)			
Total Petroleum Hydrocarbons	3 / 4	13500 / 382000	NA

* Refer to Table 4-1 for explanation of Act 307 footnotes.
NA - Not Available.

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Table 4-42 Data Summary Table: Subsurface Soil, Site 3-Former Site of County Garage
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations µg/kg	Act 307* Cleanup Criteria µg/kg
Aromatic Volatiles (ppb)			
1,3-Dimethylbenzene	1 / 8	0.013 / 0.013	5600
Halogenated Volatiles (ppb)			
1,1,2,2-Tetrachloroethane	1 / 8	0.33 / 0.33	3.6
Trichloroethylene	1 / 8	0.2 / 0.2	44
1,2,3-Tricloropropane	1 / 8	0.5 / 0.5	800
Semivolatiles (ppb)			
2-Methylnaphthalene	1 / 8	49 / 49	ID
Acenaphthene	1 / 8	190 / 190	24000
Anthracene	1 / 8	310 / 310	140000
Benzo(a)anthracene	1 / 8	520 / 520	1800
Benzo(a)pyrene	1 / 8	350 / 350	180(G)
Benzo(b)fluoranthene	1 / 8	770 / 770	1800
Benzo(ghi)perylene	1 / 8	110 / 110	180(G)
Benzo(k)fluoranthene	1 / 8	770 / 770	18,000
Carbazole	1 / 8	230 / 230	
Chrysene	1 / 8	530 / 530	180,000
Dibenzofuran	1 / 8	150 / 150	ID
Fluoranthene	1 / 8	140 / 1400	17000
Fluorene	1 / 8	220 / 220	17000
Indeno(1,2,3-c,d)pyrene	1 / 8	190 / 190	1800
Naphthalene	1 / 8	170 / 170	5000
Phenanthrene	1 / 8	1500 / 1500	500
Pyrene	1 / 8	1000 / 1000	10000
bis(2-Ethylhexyl)phthalate	3 / 8	37 / 210	92000(G)
Metals (ppb)			
Arsenic	3 / 8	480 / 680	5800
Chromium	8 / 8	2200 / 4900	18000
Copper	5 / 8	1900 / 3100	32000
Lead	8 / 8	840 / 5500	21000
TPH (ppb)			
Total Petroleum Hydrocarbons	5 / 8	7200 / 392000	NA

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Table 4-43 Data Summary Table: Groundwater, Site 3-Former Site of County Garage
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/l))	Act 307* Cleanup Criteria (µg/l)
Aromatic Volatiles (µg/l)			
Benzene	1 / 8	0.51 / 0.51	1.2
Ethylbenzene	1 / 8	1.4 / 1.4	74{R}
Styrene	1 / 8	0.11 / 0.11	1.2
Halogenated Volatiles (µg/l)			
1,1,1,2-Tetrachloroethane	1 / 8	0.18 / 0.18	1.3
Chloroethane	1 / 8	0.14 / 0.14	9.1
Chloroform	4 / 8	0.13 / 0.63	5.6
Methyl chloride	1 / 8	0.14 / 0.14	54
Methylene chloride	2 / 8	0.077 / 0.28	4.6
Tetrachloroethylene	1 / 8	0.079 / 0.079	0.7
Trichloroethylene	1 / 8	0.07 / 0.07	2.2
Low Con. Semivolatiles (µg/l)			
Di-n-butyl phthalate	3 / 8	0.8 / 0.8	840
Diethyl phthalate	2 / 8	0.5 / 7	5200
Dimethyl phthalate	1 / 8	1 / 1	70000
Phenol	1 / 8	0.8 / 0.8	4200
Metals (µg/l)			
Arsenic	1 / 8	9.9 / 9.9	
Cadmium	1 / 8	4.6 / 4.6	
Chromium	1 / 8	21.1 / 21.1	
Copper	1 / 8	25.4 / 25.4	
Lead	1 / 8	12.9 / 12.9	
Lead, Dissolved	1 / 8	2 / 2	4{C,O}
Nickel	1 / 8	18.6 / 18.6	
Selenium	1 / 8	4.4 / 4.4	
Zinc	2 / 8	10.9 / 55.9	
Zinc, Dissolved	1 / 8	5.9 / 5.9	2300{C}

*Refer to Table 4-1 for explanation of Act 307 footnotes.
1) Criteria are presented for dissolved metals only.

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4.9.2 Exposure Assessment

The purpose of the exposure assessment is to estimate the type and magnitude of human receptor exposure to chemicals of potential concern resulting from Site 3 activities. The following exposure assessment components are evaluated in this section:

- Characterization of the exposure setting (Section 4.9.2.1)
- Identification of exposure pathways/receptors (Section 4.9.2.2)
- Estimation of chemical concentrations at receptors (Section 4.9.2.3)
- Estimation of on-site child and adult intake values (Section 4.9.2.4).

4.9.2.1 Characterization of the Exposure Setting

Site 3 is the site of the former county garage (Figure 1-6). The area is grass covered with the exception of areas where gravel roads dissect the site. The facility motor pool (Site 2) is located approximately 91 m (100 yd) east of the site.

The soils at Site 3 consist of glacial material, composed of medium- to coarse-grained sands with permeabilities ranging from 4.2 x 10^{-2} cm/s (119.1 ft/day) to 1.4 x 10^{-2} cm/s (39.7 ft/day). A medium-stiff plastic clay was detected at the site. The measured vertical hydraulic conductivity of the clay was 2.1 x 10^{-6} cm/s (5.9 x 10^{-3} ft/day). The low vertical hydraulic conductivity indicates that the clay unit could act as an aquitard. The thickness of the clay varied from 0.6 to 3 m (2 to 10 ft) thick in two borings located 152 m (500 ft) apart.

Groundwater at Site 3 occurs within the shallow aquifer at depths ranging from approximately 3 to 5.8 m (10 to 19 ft) below ground surface. Groundwater flow direction is north toward the sinkhole, located approximately 1,067 m (3,500 ft) north of Site 3. A nested well pair was used to determine hydraulic conductivity in the shallow aquifer. The hydraulic conductivity of the upper portion of the aquifer (well CG3MW4) was calculated at 2.5 x 10^{-2} cm/s (72 ft/day) while the lower portion of the aquifer (well CG3MW5) was calculated at 1.8 x 10^{-1} cm/s (497 ft/day). The difference in hydraulic head between the two wells is 0.6 cm (0.02 ft), indicating no component of vertical flow at Site 3 within the surficial aquifer. The capacity of the surficial aquifer at Site 3 is deemed sufficient to support potential future production wells.

The drinking water supply for the Alpena CRTC consists of on-base production wells. PW1, the main production well is located northwest of Site 3. This well is screened in the limestone aquifer. PW2 and PW3 are located west of the site. PW2 is screened in both the shallow and limestone aquifer while PW3 is screened in the shallow aquifer. Shallow groundwater is flowing north toward the sinkhole at Site 3, therefore little potential exists for contaminants in the shallow groundwater to enter PW2 or PW3. The direction of groundwater flow within the limestone aquifer is not known at this time. Off-site residential wells lie to the north, south, and east of Alpena CRTC. All residential wells are completed in the limestone aquifer (drilling logs supplied by Alpena County Health Department).

4.9.2.2 Identification of Exposure Pathways/Receptors

The ANG holds the lease on the land until 2039; therefore, the current landuse has also been evaluated for future exposure. No full-time employees are located at Site 3. Building 37 located on the site is used by training personnel during the two-week training sessions which take place from April through September. Families of training personnel may visit during the weekends and use the recreational facilities. Although shallow groundwater from Site 3 flows toward the sinkholes, there is no known recreational use of the sinkhole.

Future residential land-use is deemed highly improbable due to the location of the land in a rural area with low growth. An alternate future recreational land-use scenario has been evaluated. This scenario assumes that the Alpena CRTC is used as a recreational area.

The following potential current exposure pathways and receptors were identified:

- Incidental ingestion of soils by facility personnel
- Dermal contact of soils by facility personnel
- Inhalation of fugitive dust from surface soils by facility personnel
- Ingestion of contaminated bedrock aquifer groundwater by on-site personnel or off-site residences.

The following future exposure pathways were identified:

- Inhalation of fugitive dust by construction workers,
- Future incidental ingestion of soils by construction workers
- Future dermal contact of soils by construction workers
- Ingestion of contaminated groundwater from future down gradient shallow groundwater wells by adults and children
- Inhalation of airborne chemicals from groundwater use from future down gradient shallow aquifer wells by adults and children
- Dermal absorption of contaminated groundwater from future down gradient shallow aquifer groundwater wells by adults and children
- Future incidental ingestion of contaminated surface water by adults and children playing in the sinkhole

- Future dermal absorption of contaminated surface water by adults and children playing in the sinkhole
- Future ingestion of contaminated fish caught in the sinkhole by adults and children
- Future ingestion of contaminated bedrock aquifer groundwater by on-site personnel or off-site resident.

Receptors include excavation workers, recreational adults, and recreational children.

Because no current chemicals of potential concern were identified in the surface soil 0 to 0.6 m (0 to 2 ft) at Site 3, the following current exposure pathways are considered incomplete and are eliminated from further consideration:

- Ingestion of contaminated soil
- Dermal contact with contaminated soil
- Soil inhalation.

No chemicals of potential concern were identified in the shallow aquifer, consequently, the following future exposure pathways are considered incomplete and eliminated from further consideration:

- Future inhalation of airborne chemicals from shallow aquifer wells
- Future dermal contact of shallow aquifer groundwater
- Future ingestion of shallow aquifer groundwater.

The exposure pathways involving the sinkhole are addressed in Section 4.10, Site 4 Risk Assessment. Pathways involving the bedrock aquifer will be addressed qualitatively.

Based on the elimination of incomplete pathways and pathways considered elsewhere, Table 4-44 presents the future exposure pathways which are considered complete and are addressed in this section.

4.9.2.3 Estimation of Chemical Concentrations at Receptors

The 95 percent UCL of the arithmetic mean, as outlined in Section 4.2, was calculated as the chemical exposure concentration for the following receptor exposure points:

- Current and future dermal contact with soils
- Future inhalation of fugitive dust
- Current and future ingestion of soils.

Table 4-44 Future Exposure Pathways – Site 3
MIANG, Alpena CRTC, Alpena, Michigan

Receptor Population	Exposure Point	Exposure Pathway
Future Land-use		
Excavation Worker	on-site	Future dermal contact with soil
Excavation Worker	on-site	Future inhalation of contaminated fugitive dust
Excavation Worker	on-site	Future ingestion of contaminated soil
Adult and Child	on-site/off-site	Ingestion of contaminated bedrock aquifer groundwater

Table 4-45 presents the calculated exposure concentration.

4.9.2.4 Estimation of Adult Intake Values

Adult CDI for carcinogenic effects and subchronic noncarcinogenic effects were estimated for exposure pathways identified in Table 4-44. Tables 4-46 through 4-48 present the formulas and assumptions used to model current and future RME intake values for each identified exposure pathway. Standard default exposure factors were used to estimate intake where applicable; acceptable exposure factor references are listed for those standard default exposure factors. Reasonable assumptions were made to quantify site-specific exposure factors. Site-specific assumptions were necessary to estimate exposure frequencies for children. It was assumed that children would be present on-site 6 months per year for 8 days per month for a total of 48 days per year for future recreational use of the area. No current use of the area occurs by children. It was further assumed that these children would be present through the childhood years (0-15 years) for an exposure duration of 15 years. Future adults were assumed to be present on-site as an employee for 250 days per year and present another 48 days for recreational activities.

Using the exposure intake models presented in Tables 4-46 through 4-48, current and future chemical intake values were estimated for the potential receptors previously identified. Table 4-49 presents a summary of the exposure assessment for future land-use at Site 3. Detailed calculations are presented in Appendix R.

4.9.3 Toxicity Assessment

Toxicity profiles for chemicals of potential concern were presented previously in Section 4.4.1, Toxicity Profiles. Section 4.4.2, Toxicity Values, presents the toxicity values for chemicals of potential concern.

4.9.4 Risk Characterization

The potential risks associated with the chemicals of concern were evaluated as outlined in Section 4.5. Section 4.9.4.1 presents the risk characterization for current land-use and

Table 4-45
Reasonable Maximum Exposure Concentrations - Site 3
MIANG, Alpena CRTC, Alpena, Michigan

Matrix	Compound	Units	Arithmetic Mean	N	Maximum Value	Minimum Value	95% UCL
Surface and Subsurface Soil							
SUBSOIL	Benzo(a)pyrene	ug/kg	188	10	350	170	221
SUBSOIL	Dibenzofuran	ug/kg	168.3	10	173	150	172
SUBSOIL	Phenanthrene	ug/kg	316.5	10	1500	170	559

IF 95% UCL is greater than the maximum value, then the maximum value is the reasonable maximum exposure concentration.

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Table 4-46 Model for Estimating Future Chemical Intake by Adults Through Soil Ingestion-Site 3
MIANG, Alpena CRTC, Alpena, Michigan

$$Intake\ (mg/kg\text{-}day) = \frac{CS \times IR \times CF \times FI \times EF \times ED}{BW \times AT}$$

where:

CS	=	Chemical Concentration in Soil (mg/kg)
IR	=	Ingestion rate (mg/day)
CF	=	Conversion Factor (10^{-6} kg/mg)
FI	=	Fraction Ingested from Contaminated Source (unitless)
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Construction Worker[1]
Ingestion Rate (IR) (mg/day)	480 mg/day
Fraction Ingested	1
Exposure Frequency (days/yr)	250 days/yr
Age Group (year)	16-65 year
Exposure Duration (years)	.08 year
Body Weight (kg)	70
Averaging Time (years), (noncarcinogenic)	.08

Notes:
1) All values from U.S. EPA, 1991.
2) Site specific assumption - see 4.9.2.4

Table 4-47 Model for Estimating Future Chemical Absorbed Dose by Adults through Dermal Contact with Soils - Site 3
MIANG, Alpena CRTC, Alpena, Michigan

$$\textit{Absorbed Dose (mg/kg-day)} = \frac{CS \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

where:

CS	=	Chemical Concentration in Soil (mg/kg)
CF	=	Conversion Factor (10^{-6} kg/mg)
SA	=	Skin Surface Area Available for Contact (cm^2/event)
AF	=	Soil to Skin Adherence Factor (mg/cm^2)
ABS	=	Absorption Factor (unitless)
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Construction Worker
Surface area (cm^2/day)	3,120[1]
Soil to Skin Adherence Factor (mg/cm^2/day)	2.77
Absorption Factor	
metals[2]	0.01 metals[2]
organics	0.25 organics
Exposure Frequency (days/yr)	250[3]
Exposure Duration (years)	0.08[2]
Body Weight (kg)	70[3]
Averaging Time (years), (noncarcinogenic)	0.08

Notes:
1) U.S. EPA, 1989b - Total of arms and hands
2) estimate - see 4.9.2.4
3) U.S. EPA, 1991.

Table 4-48 Model for Estimating Future Intake by Adults through Inhalation of Soil - Site 3
MIANG, Alpena CRTC, Alpena, Michigan

$$Intake\ (mg/kg\text{-}day) = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$$

where:

CA	=	Contaminant Concentration in Air (mg/m^3)
IR	=	Inhalation Rate (m^3/hour)
ET	=	Exposure Time (hours/day)
EF	=	Exposure Frequency (days/year)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:

where:

Ca	=	$D_L \times C_S \times CF$
D_L	=	Dust loading factor (g of soil/m^3 of air)
C_S	=	Conversion factor (10^{-3} mg/g)

(DOE, 1989)
Default dust loading factors: (DOE, 1983)
construction work - 600 g/m^3
construction traffic - 400 g/m^3

	Excavation Worker[1]
g/m^3Inhalation Rate (m^3/hr)	20
Exposure Time (hrs/day)	8
Exposure Frequency (days/yr)	250
Exposure Duration (years)	.08
Body Weight (kg)	70
Averaging Time (years)	
Carcinogens	70
Noncarcinogens	.08

Notes:
1) All values from U.S. EPA, 1991.

Table 4-49
Exposure Assessment - Future Land Use - Site 3
MIANG, Alpena CRTC, Alpena, Michigan

Population	Exposure Pathway	Chemical	Chronic Daily Intake (CDI) (mg/kg-day) Carcinogenic Effects	Chronic Daily Intake (CDI) (mg/kg-day) Noncarcinogenic Effects	Subchronic Daily Intake (SDI) (mg/kg-day) Noncarcinogenic Effects
Excavation Worker	Ingestion of chemicals in the soil	Benzo(a)pyrene	1.2E-09		1.0E-06
		Dibenzofuran	9.3E-10		8.1E-07
		Phenanthrene	3.0E-09		2.6E-06
	Dermal contact with soil	Benzo(a)pyrene	5.3E-09		4.7E-06
		Dibenzofuran	4.2E-09		4.0E-06
		Phenanthrene	1.4E-08		1.2E-05
	Inhalation of fugitive dust released from soil	Benzo(a)pyrene	4.9E-09		4.3E-06
		Dibenzofuran	5.0E-09		5.3E-06
		Phenanthrene	3.1E-09		2.7E-06

Section 4.9.4.2 presents the future land-use risk characterization.

4.9.4.1 Current Land-Use Conditions

No chemicals of potential concern were identified for the current land-use conditions, therefore no risk characterization was performed.

4.9.4.2 Future Land-Use Conditions

Table 4-50 presents future cancer risk estimates for the excavation worker. Detailed calculations are presented in Appendix R. Each table presents chemical-specific cancer risks, pathway cancer risks, and total exposure cancer risks for the excavation worker.

Future carcinogenic risks exceeding 1×10^{-6} are calculated for dermal contact with soil by the recreational child:

All calculated chemical-specific risks exceed 1×10^{-6} for the dermal contact with soil pathway.

For the future recreational adult, cancer risks exceeding 1×10^{-6} are calculated for dermal contact with soil. All chemical-specific risks for the dermal contact pathway exceed 1×10^{-6}. No chemical-specific risk above 1×10^{-6} is calculated for the soil ingestion pathway.

For the future excavation worker, dermal contact with soil exceeds the 1×10^{-6} reference level. No chemical-specific cancer risks above 1×10^{-6} are calculated for this pathway.

Subchronic HI estimates for the future excavation worker are presented in Table 4-51. No chemical-specific chronic HQ or pathway HI is calculated above the reference level of 1 for the future recreational child or adult. Total exposure HI is below 1, indicating low potential for adverse noncarcinogenic health effects.

No chemical-specific subchronic HQ or pathway HI is calculated above the reference level of 1 for the future excavation worker. Total exposure HI is below 1 indicating low potential for adverse noncarcinogenic health effects.

4.9.5 Risk Assessment Uncertainties

This section presents a discussion of uncertainties involved in the process of quantifying risk for human receptors. Uncertainties involved in the exposure assessment, toxicity assessment, HI, and cancer risk estimation are discussed separately.

4.9.5.1 Exposure Assessment Uncertainties

Uncertainty in the exposure assessment is a function of the completeness of site data, assumptions that simplify and approximate actual current or future site conditions, and professional judgement used in developing and evaluating various parameters. Assumptions and inferences must be made to develop exposure scenarios. These assumptions and

Table 4-50
Future Carcinogenic Risk Estimates for the Excavation Worker - Site 3
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Ingestion of chemicals in the soils.			
Benzo(a)pyrene	9E-09		
Dibenzofuran	0E+00		
Phenanthrene	0E+00		
		9E-09	
Exposure Pathway: Dermal contact with soil.			
Benzo(a)pyrene	2E-07		
Dibenzofuran	0E+00		
Phenanthrene	0E+00		
		2E-07	
Exposure Pathway: Inhalation of fugitive dust released from soils.			
Benzo(a)pyrene	3E-08		
Dibenzofuran	0E+00		
Phenanthrene	0E+00		
		0E+00	
Excavation Worker - Total Cancer Risk			
			2E-07

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inferences introduce uncertainties into the exposure assessment.

The exposure scenarios presented are conservative, and overestimate rather than underestimate exposure. The approach is conservative and is designed to compensate for uncertainties inherent in the exposure assessment. The use of very conservative health-protective exposure factors in the exposure assessment process results in final intake values that are extremely conservative. RME chronic intake values may be overestimated by one to two orders of magnitude.

In quantifying exposure levels, the chemicals are assumed to be uniformly distributed over the defined area, thus resulting in a uniform exposure level. Chemical analytical data were obtained from a directed sampling program, i.e., sampling locations were generally selected on the basis of where contaminants were expected to be present. Sampling zones found to be free of contamination received less investigation. This sampling scheme tends to greatly overestimate the overall chemical concentrations at a site.

The model used for inhalation of fugitive dust assumes no dilution of particulates over distance, and assumes all particles are respirable, which results in an overestimation of risk.

Finally, the assumption is made that human exposure remains constant over the lifetime of an individual. In actuality, lifestyle changes due to age and actual residence time will alter the projected exposure durations. Movement of individuals in and out of the potentially exposed community also affects exposure duration.

4.9.5.2 Toxicity Assessment

RfDs developed by the EPA are generally considered to have uncertainty spanning an order of magnitude or more. Consequently, total exposure HIs for the resident child and adult may be estimated high or low by an order of magnitude or more.

Low confidence by EPA in an RfD value, such as low confidence in the Cr (VI) oral RfD, indicates high uncertainty in the accuracy of the toxicity value. High uncertainty indicates that the value may change in the future if additional toxicity data where to become available. Conversely, high confidence by the EPA in an RfD indicates low uncertainty in the accuracy of the toxicity value.

SFs developed by the EPA are generally conservative and represent the upper bound limit of the probability of a cancer response. Thus, the actual cancer risk due to exposure to the chemicals of concern is likely to be lower than the estimated risk.

A second area of uncertainty is those chemicals which were not included in the quantitative assessment because of lack of carcinogenic or noncarcinogenic toxicity values. Chemicals lacking RfD values include diberzofuran, and those lacking SFs include phenanthrene and dibenzofuran. The total risk without considering these chemicals is underestimated.

4.9.5.3 Risk Estimates

The uncertainties involved in combining the pathways are considered minimal, as the inhalation dermal and ingestion pathways could reasonably contribute to exposure of the same individual over the same period of time. Assumption of dose accumulation ignores possible synergisms and antagonisms among chemicals, but does prevent underestimation of risks.

4.9.6 Conclusions

A summary of future carcinogenic and noncarcinogenic risks was presented previously in Tables 4-50 and 4-51.

For the future excavation worker, a total cancer risk below the 1×10^{-6} reference level is calculated. A level below 1×10^{-6} indicates an acceptable level of risk.

For noncarcinogenic effects, EPA guidance considers a HI greater than 1 to indicate potential for adverse noncarcinogenic health-effects (EPA, 1989). It has been demonstrated that the future HIs for the excavation worker are below the reference level, indicating a low potential for adverse noncarcinogenic health effects.

Uncertainties in the human health assessment were discussed previously in Section 4.9.5. The major uncertainty in the health assessment for Site 3 is the soil concentration used as the reasonable maximum concentration throughout the site. In reality the chemicals of concern are limited in areal extent and the risk to receptors is limited to a small portion of the site.

4.10 SITE 4 - THIRD FIRE TRAINING AREA RISK ASSESSMENT

A baseline risk assessment was conducted for Site 4, Third Fire Training Area, to estimate the health risk for human receptors.

Section 4.10.1 identifies the chemicals of potential concern. Section 4.10.2 presents an exposure assessment for human receptors. The toxicity assessment for chemicals of potential concern was previously presented in Section 4.4. The risk characterization for carcinogenic and noncarcinogenic effects is presented in Section 4.10.4. Uncertainties in the health assessment are discussed in Section 4.10.5. Section 4.10.6 presents a summary of total carcinogenic risk and the total exposure HIs for on-site adults and children.

4.10.1 Identification of Chemicals of Potential Concern

Chemicals of potential concern at Site 4 were identified for groundwater, surface water, and sediment through the process outlined in Section 4.2. The soils at Site 4 are part of a source removal action planned at Alpena CRTC and are not considered in this risk assessment.

Table 4-51
Estimate of Future Noncarcinogenic Effects for the Excavation Worker - Site 3
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of chemicals in the soils.			
Benzo(a)pyrene	3E-06		
Dibenzofuran	0E+00		
Phenanthrene	9E-06		
		1E-05	
Exposure Pathway: Dermal contact with soil.			
Benzo(a)pyrene	9E-05		
Dibenzofuran	0E+00		
Phenanthrene	2E-04		
		3E-04	
Exposure Pathway: Inhalation of fugitive dust released from soils.			
Benzo(a)pyrene	1E-05		
Dibenzofuran	0E+00		
Phenanthrene	2E-03		
		2E-03	
Excavation Worker - Total Hazard Index			
			2E-03

4.10.1.1 Selection of Chemicals of Potential Concern in the Shallow Aquifer

Table 3-15 presents a summary of the validated groundwater data collected during the RI. The complete data set is included in Appendix L. The three rounds of groundwater data collected prior to the RI are presented in Appendix N and O, but were not used to estimate risk. Table 4-52 presents a summary of the range of detected concentrations, the number of detections, and the MDNR criteria used in the evaluation.

No chemicals were detected above the Act 307 Type B cleanup criteria, consequently, no chemicals of potential concern were identified for the shallow aquifer.

4.10.1.2 Selection of Chemicals of Potential Concern in the Surface Water

The sinkhole present at Site 4 receives discharge from almost all areas of the facility. Table 3-14 presents a summary of the validated surface water data. The complete data set is included in Appendix L. Data collected during the SI is included in Appendix N but was not used to estimate risk due to the age of the data.

Table 4-53 presents a summary of the range of detected concentrations and the number of detections. 1,2 dichlorobenzene, chloroform, diethyl phthalate, phenol, and zinc, dissolved were detected below acceptable detection limits, as defined by MERA Operational Memorandum #8, 1993 and were deleted from consideration. The following compounds were detected above acceptable detection limits and have been identified as chemicals of potential concern:

- Trichloroethylene
- Selenium, dissolved.

Additionally, all chemicals of concern in the groundwater from those sites which discharge groundwater into the sinkhole have been identified as chemicals of potential concern. These chemicals are listed below:

- Carbon tetrachloride
- Tetrachloroethylene
- Arsenic
- Benzene
- Styrene
- 1,2 dichlorobenzene
- 1,4 dichlorobenzene
- 2 methylnapthalene

Table 4-52 Data Summary Table: Groundwater, Site 4-Third Fire Training Area
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/l)	Act 307* Cleanup Criteria (µg/l)
Aromatic Volatiles (µg/l)			
1,3-Dimethylbenzene	2 / 3	0.034 / 0.066	280{R}
Ethylbenzene	1 / 5	0.1 / 0.1	74{R}
Halogenated Volatiles (µg/l)			
Methylene chloride	3 / 5	0.053 / 0.063	4.6
Low Con. Semivolatiles (µg/l)			
Diethyl phthalate	1 / 5	0.5 / 0.5	5200
Phenol	1 / 5	0.8 / 0.8	4200
bis(2-Ethylhexyl)phthalate	1 / 5	4 / 4	2.5
Metals (µg/l)[1)]			
Arsenic	4 / 5	4.8 / 23	
Beryllium	3 / 5	1.4 / 2.9	
Cadmium	1 / 5	8.1 / 8.1	
Chromium	5 / 5	16.5 / 88	
Copper	3 / 5	79.9 / 120	
Lead	5 / 5	16.4 / 62.7	
Nickel	3 / 5	56 / 90.5	
Zinc	5 / 5	34.6 / 246	

* Refer to Table 4-1 for explanation of Act 307 footnotes.
[1)]Criteria are presented for dissolved metals only.

Table 4-53 Data Summary Table: Surfacewater, Site 4-Third Fire Training Area
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/l)	Acceptable Method Detection Limits (µg/l)
Aromatic Volatiles (µg/l)			
1,2-Dichlorobenzene	1 / 3	0.16 / 0.16	1.0
Halogenated Volatiles (µg/l)			
Chloroform	2 / 3	0.2 / 0.49	1.0
Trichoroethylene	2 / 3	0.095 / 1.2	1.0
Low Con. Semivolatiles (µg/l)			
Diethyl phthalate	1 / 3	0.5 / 0.5	5
Phenol	1 / 3	0.5 / 0.5	5
Metals (µg/l)			
Selenium, Dissolved	1 / 3	5.6 / 5.6	5
Zinc, Dissolved	3 / 3	5 / 7.3	20

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- Lead.

4.10.1.3 Selection of Chemicals of Potential Concern within the Sediment

Table 3-13 presents a summary of the validated sediment data collected during the RI. Only the sediments along the bank of the sinkhole (SD01-SD10A) were used in the evaluation. Table 4-54 presents a summary of the range of detected concentrations and the number of detections. Data collected prior to the RI is included in Appendix L.

Trichloroethylene and di-n-butyl phthalate were detected below acceptable MDLs and were deleted from further consideration. Arsenic, chromium, lead, and nickel were below soil background levels and were also omitted. The following chemicals were identified as chemicals of potential concern:

- Methylene chloride
- 4-methylphenol
- Selenium.

4.10.2 Exposure Assessment

The purpose of the exposure assessment is to estimate the type and magnitude of human receptor exposure to chemicals of potential concern resulting from Site 4 activities. The following exposure assessment components are evaluated in this section:

- Characterization of the exposure setting (Section 4.10.2.1)
- Identification of exposure pathways/receptors (Section 4.10.2.2)
- Estimation of chemical concentrations at receptors (Section 4.10.2.3)
- Estimation of on-site child and adult intake values (Section 4.10.2.4).

4.10.2.1 Characterization of the Exposure Setting

Site 4 lies within the training area of the Alpena CRTC (Figure 1-7). The site consists of a concrete pad where fuel was ignited for fire training exercises and a pipeline which is grass covered. The soils at Site 4 are scheduled to be remediated under a source removal action and are not considered in this risk assessment. The land surrounding Site 4 is primarily grassed fields. Directly southwest of Site 4 is a large sinkhole. The sinkhole is heavily vegetated with trees and shrubs. No recreational activities currently occur at the sinkhole.

Groundwater beneath Site 4 flows toward the sinkhole. Groundwater discharges from all directions into the sinkhole. Several visible springs discharge water into the sinkhole. Depth to groundwater at Site 4 is 7 to 9 m (23 to 30 ft) bgs. A thin clay layer 0.3 to 0.6 m (1 to 2 ft) thick is present between the shallow aquifer and the limestone. Depth to limestone is

Table 4-54 Data Summary Table: Sediment, Site 4-Third Fire Training Area
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/kg)	Range of Background Concentrations (µg/kg)	Acceptable Method Detection Limit (µg/kg)
Halogenated Volatiles (ppb)				
Methylene chloride	8 / 10	1.9 / 16	ND / ND	10
Trichloroethylene	1 / 10	0.089 / 0.089	ND / ND	10
Semivolatiles (ppb)				
4-Methylphenol	2 / 10	130 / 130	ND / ND	NA
Di-n-butyl phthalate	1 / 10	56 / 56	ND / ND	330
Metals (ppb)				
Arsenic	8 / 10	530 / 2300	5800	
Chromium	10 / 10	2400 / 10000	18000	
Lead	1 / 10	1600 / 1600	21000	
Nickel	1 / 10	4500 / 4500	20000	
Selenium	4 / 10	420 / 1100	700	
TPH (ppb)				
Total Petroleum Hydrocarbons	14 / 28	10000 / 1060000	ND / ND	

ND - Not Determined.

approximately 10.7 m (35 ft). The sinkhole is hydraulically connected to the deeper aquifer.

The water supply for the facility consists of on-site production wells. These wells are located south of Site 4. Residential wells are located north, south, and east of the Alpena CRTC. These residential wells are all completed in the limestone aquifer.

4.10.2.2 Identification of Exposure Pathways/Receptors

The ANG holds the lease on the land until 2039; therefore, the current land-use has been evaluated for future exposure. No full-time employees are located at the site. The area is used from the months of April through September for two-week training sessions. Families of personnel training at the facility visit on the weekends and use the recreational facilities at the CRTC. The sinkhole is not used for recreational purposes.
An alternate future land-use which will be considered is recreational use of the Site 4 area. Future residential land-use is deemed highly improbable due to the location of the land in a rural area with low growth.

The following potential current exposure pathways and receptors were identified:

- Ingestion of contaminated bedrock aquifer groundwater by off-site residents
- Ingestion of contaminated production well water by facility personnel and visitors
- Dermal contact of contaminated production well water by facility personnel and visitors
- Inhalation of VOCs volatilized into the air from contaminated production well water by facility personnel and visitors.

The following potential future exposure pathways and receptors were identified:

- Future ingestion of contaminated surface water by adults and children while swimming or playing in the sinkhole
- Future dermal absorption of contaminated surface water by adults and children playing in the sinkhole
- Future dermal contact with sediments at the bank of the sinkhole by adults and children
- Future ingestion of sediments at the bank of the sinkhole by adults and children
- Future inhalation of VOCs from sediments at the bank of the sinkhole by adults and children
- Future ingestion of contaminated fish caught in the sinkhole by adults and children

- Future ingestion of groundwater by off-site residents

- Future ingestion of contaminated groundwater by off-site residents.

No contaminants were detected in the shallow groundwater at Site 4, consequently, no potential exists for contamination of the limestone aquifer by the Site 4 shallow groundwater. The potential does, however, exist for any contaminants entering the sinkhole to migrate to the deeper aquifer. Consequently, pathways involving the limestone aquifer have been retained for consideration. The on-site production well risk characterization is assessed in Section 4.7 off-site receptors are addressed qualitatively in Section 4.10.6.

The bank of the sinkhole is heavily vegetated with 95 percent of the shoreline inaccessible. Consequently, future inhalation of VOCs volatilized from sediments at the bank of the sinkhole is considered an incomplete pathway and is not retained for further consideration.

Based on the elimination of incomplete pathways and those considered elsewhere, the current and future pathways which are considered complete are presented in Table 4-55.

4.10.2.3 <u>Estimation of Chemical Concentrations at Receptors</u>

The 95 percent UCL of the arithmetic mean, as outlined in Section 4.2, was calculated as the chemical exposure concentration for the future sinkhole sediments. Future concentrations of chemicals of potential concern in surface water were predicted using a two-dimensional MOC solute transport model. The model estimates the maximum concentration of chemicals of concern which would enter the sinkhole over time. Chemicals of concern from all sites were considered. Concentrations are presented in Table 4-56. Details of the model are included in Appendix S.

4.10.2.4 <u>Estimation of On-site Child and Adult Intake Values</u>

On-site child and adult CDI values for carcinogenic effects and subchronic noncarcinogenic effects were estimated for exposure pathways identified in Table 4-62. Tables 4-64 through 4-68 present the formulas and assumptions used to model future RME intake values for each identified exposure pathway. Standard default exposure factors were used to estimate intake where applicable; acceptable exposure factor references are listed for those standard default exposure factors. Reasonable assumptions were made to quantify site-specific exposure factors. Site-specific assumptions were necessary to estimate exposure frequencies for children. Children of visiting or full-time employees may use the on-site facilities during the weekends. It was assumed that children would be present on-site 6 months per year for 8 days per month for a total of 48 days per year. It was further assumed that these children would be present through the childhood years (0-15 years) for an exposure duration of 15 years. Ingestion of soil was assumed to occur in the 0-6 year old child. The exposure frequency of 48 days per year was assumed to also be reasonable should the land become solely recreational.

Table 4-55 Current and Future Exposure Pathways - Site 4
MIANG, Alpena, CRTC, Michigan

Receptor Population	Exposure Point	Exposure Pathway
Current Land-use		
Adult and Child	off-site	Ingestion of contaminated groundwater
Future Land-use		
Adult and Child	on-site	Future ingestion of contaminated surface water from sinkhole
Adult and Child	on-site	Future dermal absorption of chemicals in surface water from sinkhole
Adult and Child	on-site	Future dermal contact with contaminated sinkhole sediments
Adult and Child	on-site	Future ingestion of contaminated sediments from the bank sinkhole
Adult and Child	on-site	Future ingestion of contaminated fish from sinkhole
Adult and Child	off-site	Future ingestion of contaminated groundwater

Using the exposure intake models presented in Tables 4-57 through 4-61, future chemical intake values were estimated for the potential receptors previously identified. Table 4-62 presents a summary of the exposure assessment for future land-use at Site 4. Detailed calculations are presented in Appendix S.

4.10.3 Toxicity Assessment

Toxicity profiles for chemicals of potential concern were presented previously in Section 4.4.1 Toxicity Profiles. Section 4.4.2, Toxicity Values, presents the toxicity values for chemicals of potential concern.

4.10.4 Risk Characterization

The potential risks associated with the chemicals of concern were evaluated as outlined in Section 4.5. No current potential risk exists at Site 4. The future land-use risk characterization is presented below. The risk to off-site receptors is qualitatively addressed in Section 4.10.6.

4.10.4.1 Future Land-Use Conditions

Tables 4-63 and 4-64 present cancer risk estimates for the on-site child and adult respectively. Detailed calculations are presented in Appendix S. Each table presents chemical-specific cancer risks, pathway cancer risks, and total exposure cancer risk for the on-site child and adult.

Table 4-56
Reasonable Maximum Exposure Concentrations- Site 4
MIANG, Alpena CRTC, Alpena, Michigan

Matrix	Compound	Units	Arithmetic Mean	N	Maximum Value	Minimum Value	95% UCL	Maximum Modeled Concentrations	Year Maximum Occurs
SEDIMENT	Selenium	mg/kg	0.34	12	1.1	0.155	0.49		
SEDIMENT	Methylene chloride	ug/kg	5.67	9	16	0.75	8.80		
SEDIMENT	4-Methylphenol	ug/kg	233.00	12	365	144	263.37		
SURFACEWATER	Trichloroethylene	ug/l	0.48	3	1.2	0.095	1.53		
SURFACEWATER	Selenium, dissolved	ug/l	2.10	3	3.5	1.5	4.11		
SURFACE WATER	Carbon Tetrachloride	ug/l						0.081	
SURFACE WATER	Tetrachloroethylene	ug/l						0.029	20
SURFACE WATER	Arsenic	ug/l						0.002	20
SURFACE WATER	Benzene	ug/l						1.551	
SURFACE WATER	Styrene	ug/l						0.01	
SURFACE WATER	1,2 Dichlorethane	ug/l						0.01	20
SURFACE WATER	1,4 Dichlorobenzene	ug/l						0.105	20
SURFACE WATER	2 Methylnapthalene	ug/l						0.01	
SURFACE WATER	Lead	ug/l						0.004	

If 95% UCl > the maximum value, then the maximum value is the reasonable maximum exposure concentration.

Table 4-57 Model for Estimating Future Chemical Intake by Adults and Children through Consumption of Fish Caught in Sinkhole - Site 4 MIANG, Alpena CRTC, Alpena, Michigan

$$CDI\ (mg/kg\text{-}day) = \frac{CF \times IR \times FI \times EF \times ED}{BW \times AT}$$

where:

CDI	=	Chronic Daily Intake (mg/kg-day), representing the RME.
IR	=	Ingestion rate (kg/day)
FI	=	The Fraction of total Fish Ingested which is caught from Thunderbay River (unitless).
EF	=	Exposure Frequency (days/year)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Adult	Child
Chemical Concentration in Fish[5]		
Ingestion Rate (kg/day)	0.054[1]	0.043[2]
Fraction of fish ingested (unitless)	0.50[3]	0.50[3]
Exposure Frequency (days/yr)	26[3]	26[3]
Exposure Duration (year)	25[1]	15[1]
Body Weight (kg)	70[1]	27[4]
Average Time (years), (noncarcinogenic)	25	15[1]

Notes:
1) U.S. Environmental Protection Agency, 1991.
2) Pao, Eleonore, M., 1982.
3) Site specific assumption – EF = 1 day/wk for 26 weeks.
4) U.S. Environmental Protection Agency, 1989a.
5) The chemical concentration in fish is equal to the chemical concentration in surface water x fish bioconcentration factor (BCF). The following BCFs were applied: Carbon Tetrachloride 17 (EPA, 1980c); Tetrachloroethylene 56 (MEPAS); Arsenic 1 (Sphehar); benzene 24 (MEPAS); Styrene 100 (MEPAS); 1,2 dichloroethane 2 (EPA, 1980b); 1,4-dichlorobenzene 60 (EPA, 1980c); 2 methylnapthalene 510 (MEPAS); Lead 100 (Napier); trichloroethene 39 (Howard); selenium 1

Table 4-58 Model for Estimating Future Chemical Absorbed Dose by Adults and Children through Dermal Contact with Chemicals in Sinkhole - Site 4 MIANG, Alpena CRTC, Alpena, Michigan

$$\text{Absorbed Dose (mg/kg-day)} = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

where:

CW	=	Chemical Concentration in Water (mg/ℓ).
SA	=	Skin Surface Area Available for Contact (cm^2).
PC	=	Chemical-specific Dermal Permeability Constant (cm/hr) default 8.4×10^{-4}
ET	=	Exposure Time (hours/day).
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
CF	=	Volumetric Conversion Factor for Water (1 liter/1000 cm^3)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Adult	Child
Skin Surface Area (cm^2)	19,400[1]	13,300
Dermal Permeability Constant (cm/hr)[4]	8×10^{-4} [2]	8.4×10^{-4}
Exposure Time (hours/day)	2.6[2]	2.6[2]
Exposure Frequency (days/yr)	48[3]	48[3]
Exposure Duration (years)	25[3]	15[3]
Body Weight (kg)	70[1]	27[1]
Averaging Time (years) (noncarcinogenic)	25	15

Notes:

1) U.S. Environmental Protection Agency, 1989b – Child is average for ages 6-18.
2) U.S. Environmental Protection Agency, 1989a.
3) Site specific assumption.
4) Chemical-specific permeability constants were used where available: Arsenic 1×10^{-3} (EPA, 1992), Carbon tetrachloride 2.2×10^{-2} (Tab 5-7, EPA, 1992), tetrachloroethylene 4×10^{-1} (Tab 5-3 EPA, 92); benzene 1×10^{-1} (Tab 5-3 EPA, 92); 1,2-dichloroethane 4.3×10^{-3} (Tab 5-7, EPA, 92); 1,4 dichlorobenzene 6.2×10^{-2}, (Tab 5-7, EPA 92); 2-methylnapthlane 1×10^{-3} (Tab 5-3, EPA 92); Lead 4×10^{-6} (Tab 5-3, EPA, 92), trichloroethylene, selenium.

Table 4-59 Model for Estimating Future Intake by Adults and Children through Ingestion of Surface Water while Swimming or Playing in Sinkhole - Site 4 MIANG, Alpena CRTC, Alpena, Michigan

$$CDI\ (mg/kg\text{-}day) = \frac{CW \times CR \times ET \times EF \times ED}{BW \times AT}$$

where:

CDI	=	Chronic Daily Intake (mg/kg-day), representing the RME.
CW	=	Chemical Concentration in Surface Water (mg/ℓ).
CR	=	Surface Water Contact Rate (ℓ/hour).
ET	=	Exposure Time (hours/day).
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Adult	Child
CW[4]		
Surface Water Contact Rate (mℓ/hr)	50[1]	50[1]
Exposure Time (hours/day)	2.6[2]	2.6[2]
Exposure Frequency (days/yr)	48[3]	48[3]
Exposure Duration (years)	25[3]	15[3]
Body Weight (kg)	70[1]	27[1]
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) U.S. Environmental Protection Agency, 1989b.
2) U.S. Environmental Protection Agency, 1989a.
3) Site specific assumption – Section 4.10.2.4.
4 Future Surface water concentrations in the sinkhole were modeled using current groundwater data throughout the facility. The maximum concentration of chemicals of concern in the groundwater discharging into the sinkhole over time was used as the future surface water concentrations. Any chemicals of concern currently present in the sinkhole were carried over into the future scenario

Table 4-60 Model for Estimating Future Absorbed Dose by Adults through Dermal Contact with Sediments at the Sinkhole - Site 4
MIANG, Alpena CRTC, Alpena, Michigan

$$\textit{Absorbed Dose (mg/kg-day)} = \frac{CS \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

where:

CS	=	Chemical Concentration in Soil (mg/kg)
CF	=	Conversion Factor (10^{-6} kg/mg)
SA	=	Skin Surface Area Available for Contact (cm^2/event)
AF	=	Soil to Skin Adherence Factor (mg/cm^2)
ABS	=	Absorption Factor (unitless)
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Adult	Child
Surface area (cm^2/day)	3,120[1]	1,490[1]
Soil to Skin Adherence Factor (mg/cm^2)	2.77	2.77
Absorption Factor	0.01 metals[2] 0.25 organics	0.01 0.25
Exposure Frequency (days/yr)	48[3]	48
Exposure Duration (years)	25[2]	15
Body Weight (kg)	70[3]	27
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) U.S. Environmental Protection Agency, 1989b - Total of arms and hands
2) estimate
3) U.S. Environmental Protection Agency, 1991.

Table 4-61 Model for Estimating Future Chemical Intake by Adults through Sediment Ingestion at the Sinkhole - Site 4 MIANG, Alpena CRTC, Alpena, Michigan

$$CDI\ (mg/kg\text{-}day) = \frac{CS \times IR \times CF \times FI \times EF \times ED}{BW \times AT}$$

where:

CDI	=	Chronic daily intake (mg/kg-day)
CS	=	Chemical Concentration in Soil (mg/kg)
IR	=	Ingestion Rate (mg/day)
CF	=	Conversion Factor (10^{-6} kg/mg)
FI	=	Fraction Ingested from Contaminated Source (unitless)
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Adult[1]	Child
Ingestion Rate (IR) (mg/day)	100	200
Fraction Ingested (unitless)	1	1
Exposure Frequency (days/yr)	48	48
Age Group (years)	16-65	1-6
Exposure Duration (years)	25	6
Body Weight (kg)	70	15
Averaging Time (years), (noncarcinogenic)	25	6

Notes:
1) All values from U.S. Environmental Protection Agency, 1991.

Table 4-62
Exposure Assessment - Future Land Use - Site 4
MIANG, Alpena CRTC, Alpena, Michigan

Population	Exposure Pathway	Chemical	Chronic Daily Intakes (CDI)(mg/kg-day) Carcinogenic Effects	Noncarcinogenic Effects
On-Site/Recreational Adult	Dermal contact with shoreline sediments from the sinkhole	Selenium	2.8E-08	7.9E-08
		Methylene chloride	1.3E-08	3.6E-08
		4-Methylphenol	3.8E-07	1.1E-06
	Ingestion of surface water while swimming in the sinkhole	Trichloroethylene	4.2E-08	1.2E-07
		Selenium, dissolved	1.8E-07	5.1E-07
		Carbon Tetrachloride	7.1E-09	2.0E-08
		Tetrachloroethylene	2.5E-09	7.1E-09
		Arsenic	1.7E-10	4.9E-10
		Benzene	1.4E-07	3.8E-07
		Styrene	8.7E-10	2.4E-09
		1,2-Dichloroethane	8.7E-10	2.4E-09
		1,4-Dichlorobenzene	9.2E-09	2.6E-08
		2-Methylnapthalene	8.7E-10	2.4E-09
		Lead	3.5E-10	9.8E-10
	Dermal contact with surface water from the sinkhole	Trichloroethylene	8.1E-06	2.3E-05
		Selenium, dissolved	1.2E-07	3.3E-07
		Carbon Tetrachloride	6.0E-08	1.7E-07
		Tetrachloroethylene	3.9E-07	1.1E-06
		Arsenic	6.8E-11	1.9E-10
		Benzene	5.2E-06	1.5E-05
		Styrene	2.8E-10	8.0E-10
		1,2-Dichloroethane	1.8E-09	5.0E-09
		1,4-Dichlorobenzene	2.2E-07	6.2E-07
		2-Methynapthalene	3.4E-10	9.5E-10
		Lead	5.4E-13	1.5E-12
	Consumption of fish from the sinkhole	Trichloroethylene	4.6E-07	1.3E-06
		Selenium, dissolved	3.4E-08	9.6E-08
		Carbon Tetrachloride	1.4E-08	3.8E-08
		Tetrachloroethylene	1.6E-08	4.5E-08
		Arsenic	2.0E-11	5.5E-11
		Benzene	3.7E-07	1.0E-06
		Styrene	9.8E-09	2.7E-08
		1,2 Dichlorethane	2.0E-10	5.5E-10
		1,4 Dichlorobenzene	6.2E-08	1.7E-07
		2 Methylnapthalene	5.0E-08	1.4E-07
		Lead	3.9E-09	1.1E-08
	Ingestion of shoreline sediments while playing in the sinkhole	Selenium	3.3E-08	9.2E-08
		Methylene chloride	5.9E-10	1.7E-09
		4-Methylphenol	1.8E-08	4.9E-08

Table 4-62 (continued)
Exposure Assessment - Future Land Use - Site 4
MIANG, Alpena CRTC, Alpena, Michigan

Population	Exposure Pathway	Chemical	Chronic Daily Intakes (CDI)(mg/kg-day) Carcinogenic Effects	Noncarcinogenic Effects
Recreational Child	Dermal contact with shoreline sediments from the sinkhole	Selenium	2.1E-08	9.8E-08
		Methylene chloride	9.5E-09	4.4E-08
		4-Methylphenol	2.8E-07	1.3E-06
	Ingestion of surface water while swimming in the sinkhole	Trichloroethylene	4.6E-07	3.0E-07
		Selenium, dissolved	3.4E-08	1.3E-06
		Carbon Tetrachloride	1.1E-08	5.1E-08
		Tetrachloroethylene	3.9E-09	1.8E-08
		Arsenic	2.7E-10	1.3E-09
		Benzene	2.1E-07	9.8E-07
		Styrene	1.4E-09	6.3E-09
		1,2-Dichloroethane	1.4E-09	6.3E-09
		1,4-Dichlorobenzene	1.4E-08	6.6E-08
		2-Methylnapthalen	1.4E-09	6.3E-09
		Lead	5.4E-10	2.5E-09
	Dermal contact with surface water from the sinkhole	Trichloroethylene	8.7E-06	4.0E-05
		Selenium, dissolved	1.3E-07	5.9E-07
		Carbon Tetrachloride	6.4E-08	3.0E-07
		Tetrachloroethylene	4.2E-07	2.0E-06
		Arsenic	7.2E-11	3.4E-10
		Benzene	5.6E-06	2.6E-05
		Styrene	3.0E-10	1.4E-09
		1,2-Dichloroethane	1.9E-09	8.9E-09
		1,4-Dichlorobenzene	2.3E-07	1.1E-06
		2-Methynapthalene	3.6E-10	1.7E-09
		Lead	5.8E-13	2.7E-12
	Consumption of fish from the sinkhole	Trichloroethylene	5.7E-07	2.7E-06
		Selenium, dissolved	4.3E-08	2.0E-07
		Carbon Tetrachloride	1.7E-08	7.8E-08
		Tetrachloroethylene	2.0E-08	9.2E-08
		Arsenic	2.4E-11	1.1E-10
		Benzene	4.5E-07	2.1E-06
		Styrene	1.2E-08	5.7E-08
		1,2 Dichlorethane	2.4E-10	1.1E-09
		1,4 Dichlorobenzene	7.7E-08	3.6E-07
		2 Methylnapthalene	6.2E-08	2.9E-07
		Lead	4.9E-09	2.3E-08
	Ingestion of shoreline sediments while playing in the sinkhole	Selenium	7.3E-08	3.4E-07
		Methylene chloride	1.3E-09	6.2E-09
		4-Methylphenol	4.0E-08	1.8E-07

Table 4-63
Future Carcinogenic Risk Estimates for the Recreational Child - Site 4
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Dermal contact with shoreline sediments from the sinkhole			
Selenium	0E+00		
Methylene chloride	7E-11		
4-Methylphenol	0E+00		
		7E-11	
Exposure Pathway: Ingestion of surface water while swimming in the sinkhole			
Trichloroethylene	5E-09		
Selenium, dissolved	0E+00		
Carbon Tetrachloride	1E-09		
Tetrachloroethylene	2E-10		
Arsenic	5E-10		
Benzene	6E-09		
Styrene	0E+00		
1,2 Dichlorethane	1E-10		
1,4 Dichlorobenzene	3E-10		
2 Methylnapthalene	0E+00		
Lead	0E+00		
		1E-08	
Exposure Pathway: Dermal contact with surface water from the sinkhole			
Trichloroethylene	2E-07		
Selenium, dissolved	0E+00		
Carbon Tetrachloride	9E-09		
Tetrachloroethylene	2E-08		
Arsenic	1E-10		
Benzene	2E-07		
Styrene	0E+00		
1,2 Dichlorethane	2E-10		
1,4 Dichlorobenzene	6E-09		
2 Methylnapthalene	0E+00		
Lead	0E+00		
		4E-07	

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Table 4-63 (continued)
Future Carcinogenic Risk Estimates for the Recreational Child - Site 4
MIANG, Alpena CRTC, Alpena, MI

Exposure Pathway: Consumption of Fish from the sinkhole			
Trichloroethylene	2E-09		
Selenium, dissolved	0E+00		
Carbon Tetrachloride	2E-09		
Tetrachloroethylene	1E-09		
Arsenic	4E-11		
Benzene	1E-08		
Styrene	0E+00		
1,2 Dichlorethane	2E-11		
1,4 Dichlorobenzene	2E-09		
2 Methylnapthalene	0E+00		
Lead	0E+00		
		2E-08	
Exposure Pathway: Ingestion of shoreline sediments while playing in the sinkhole			
Selenium	0E+00		
Methylene chloride	1E-11		
4-Methylphenol	0E+00		
		1E-11	
Recreational Child - Total Future Cancer Risk			
			4E-07

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Table 4-64
Future Carcinogenic Risk Estimates for the On-Site/Recreational Adult - Site 4
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Dermal contact with shoreline sediments from the sinkhole			
Selenium	0E+00		
Methylene chloride	1E-10		
4-Methylphenol	0E+00		
		1E-10	
Exposure Pathway: Ingestion of surface water while swimming in the sinkhole			
Trichloroethylene	4E-10		
Selenium, dissolved	0E+00		
Carbon Tetrachloride	9E-10		
Tetrachloroethylene	1E-10		
Arsenic	3E-10		
Benzene	4E-09		
Styrene	0E+00		
1,2 Dichlorethane	8E-11		
1,4 Dichlorobenzene	2E-10		
2 Methylnapthalene	0E+00		
Lead	0E+00		
		6E-09	
Exposure Pathway: Dermal contact with surface water from the sinkhole			
Trichloroethylene	6E-08		
Selenium, dissolved	0E+00		
Carbon Tetrachloride	9E-09		
Tetrachloroethylene	2E-08		
Arsenic	1E-10		
Benzene	2E-07		
Styrene	0E+00		
1,2 Dichlorethane	2E-10		
1,4 Dichlorobenzene	5E-09		
2 Methylnapthalene	0E+00		
Lead	0E+00		
		2E-07	

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Table 4-64 (continued)
Future Carcinogenic Risk Estimates for the On-Site/Recreational Adult - Site 4
MIANG, Alpena CRTC, Alpena, MI

Exposure Pathway: Consumption of Fish from the sinkhole		
Trichloroethylene	5E-09	
Selenium, dissolved	0E+00	
Carbon Tetrachloride	2E-09	
Tetrachloroethylene	8E-10	
Arsenic	4E-11	
Benzene	1E-08	
Styrene	0E+00	
1,2 Dichlorethane	2E-11	
1,4 Dichlorobenzene	1E-09	
2 Methylnapthalene	0E+00	
Lead	0E+00	
		2E-08
Exposure Pathway: Ingestion of shoreline sediments while playing in the sinkhole		
Selenium	0E+00	
Methylene chloride	4E-12	
4-Methylphenol	0E+00	
		4E-12
Recreational Adult - Total Future Cancer Risk		
		3E-07

No carcinogenic risks were computed exceeding the 1 x 10^{-6} acceptable risk level for any chemical or exposure pathway evaluated.
These levels indicate an acceptable cancer risk exists for any future recreational activities which might occur at the sinkhole.

Tables 4-65 and 4-66 present chronic HI estimates for the on-site child and adult, respectively. Detailed calculations are presented in Appendix P. Each table presents chemical-specific HQs, pathway HIs, and total exposure HIs for the on-site child and adult. No pathway HIs were computed above the reference level of 1, indicating a low potential for adverse noncarcinogenic effects at Site 4.

4.10.5 Risk Assessment Uncertainties

This section presents a discussion of uncertainties involved in the process of quantifying risk for human receptors. Uncertainties involved in the exposure assessment, toxicity assessment, HI, and cancer risk estimation are discussed separately.

4.10.5.1 Exposure Assessment Uncertainties

Uncertainty in the exposure assessment is a function of completeness of site data, assumptions that simplify and approximate actual current of future site conditions, and professional judgement used in developing and evaluating various parameters. Assumptions and inferences must be made to develop exposure scenarios. These assumptions and inferences introduce uncertainties into the exposure assessment.

The exposure scenarios presented are conservative, and overestimate rather than underestimate exposure. The approach is conservative and is designed to compensate for uncertainties inherent in the exposure assessment. The use of very conservative health-protective exposure factors in the exposure assessment process results in final intake values that are extremely conservative. RME chronic intake values may be overestimated by one to two orders of magnitude.

In quantifying exposure levels, the chemicals are assumed to be uniformly distributed over the defined area, thus resulting in a uniform exposure level. Chemical analytical data were obtained from a directed sampling program, i.e., sampling locations were generally selected on the basis of where contaminants were expected to be present. Sampling zones found to be free of contamination received less investigation. This sampling scheme tends to greatly overestimate the overall chemical concentrations at a site.

One of the assumptions used in the exposure assessment is that the current chemical concentrations in groundwater and future modeled chemical concentrations are assumed to remain constant over exposure pathway duration and that the transport mechanisms are assumed to have reached equilibrium. This means that the levels will not decrease due to the exhaustion of the contaminant sources over the assumed exposure periods. The result of this assumption is a probable overestimation of surface water exposure point concentrations because contaminant sources will not likely remain constant over time.

Table 4-65
Estimate of Future Noncarcinogenic Effects for the Recreational Child - Site 4
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal contact with shoreline sediments from the sinkhole			
Selenium	2E-05		
Methylene chloride	8E-07		
4-Methylphenol	4E-04		
		4E-04	
Exposure Pathway: Ingestion of surface water while swimming in the sinkhole			
Trichloroethylene	4E-05		
Selenium, dissolved	3E-04		
Carbon Tetrachloride	7E-05		
Tetrachloroethylene	2E-06		
Arsenic	4E-06		
Benzene	0E+00		
Styrene	3E-08		
1,2 Dichlorethane	0E+00		
1,4 Dichlorobenzene	0E+00		
2 Methylnapthalene	2E-07		
Lead	0E+00		
		4E-04	
Exposure Pathway: Dermal contact with surface water from the sinkhole			
Trichloroethylene	2E-05		
Selenium, dissolved	8E-05		
Carbon Tetrachloride	5E-04		
Tetrachloroethylene	2E-04		
Arsenic	1E-06		
Benzene	0E+00		
Styrene	7E-09		
1,2 Dichlorethane	0E+00		
1,4 Dichlorobenzene	0E+00		
2 Methylnapthalene	6E-08		
Lead	0E+00		
		8E-04	

Table 4-65 (continued)
Estimate of Future Noncarcinogenic Effects for the Recreational Child - Site 4
MIANG, Alpena CRTC, Alpena, MI

Exposure Pathway: Consumption of Fish from the sinkhole			
Trichloroethylene	1E-04		
Selenium, dissolved	2E-05		
Carbon Tetrachloride	1E-04		
Tetrachloroethylene	9E-06		
Arsenic	4E-07		
Benzene	0E+00		
Styrene	3E-07		
1,2 Dichlorethane	0E+00		
1,4 Dichlorobenzene	0E+00		
2 Methylnapthalene	1E-05		
Lead	0E+00		
		3E-04	
Exposure Pathway: Ingestion of shoreline sediments while playing in the sinkhole			
Selenium	7E-05		
Methylene chloride	1E-07		
4-Methylphenol	4E-05		
		1E-04	
Recreational Child - Total Future Hazard Quotient			
			2E-03

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Table 4-66
Estimate of Future Noncarcinogenic Effects for the On-Site/Recreational Adult - Site 4
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal contact with shoreline sediments from the sinkhole			
Selenium	2E-05		
Methylene chloride	6E-07		
4-Methylphenol	3E-04		
		3E-04	
Exposure Pathway: Ingestion of surface water while swimming in the sinkhole			
Trichloroethylene	2E-05		
Selenium, dissolved	1E-04		
Carbon Tetrachloride	3E-05		
Tetrachloroethylene	7E-07		
Arsenic	2E-06		
Benzene	0E+00		
Styrene	1E-08		
1,2 Dichlorethane	0E+00		
1,4 Dichlorobenzene	0E+00		
2 Methylnapthalene	8E-08		
Lead	0E+00		
		1E-04	
Exposure Pathway: Dermal contact with surface water from the sinkhole			
Trichloroethylene	1E-05		
Selenium, dissolved	4E-05		
Carbon Tetrachloride	3E-04		
Tetrachloroethylene	1E-04		
Arsenic	7E-07		
Benzene	0E+00		
Styrene	4E-09		
1,2 Dichlorethane	0E+00		
1,4 Dichlorobenzene	0E+00		
2 Methylnapthalene	3E-08		
Lead	0E+00		
		4E-04	

Table 4-66 (continued)
Estimate of Future Noncarcinogenic Effects for the On-Site Recreational Adult - Site 4
MIANG, Alpena CRTC, Alpena, MI

Exposure Pathway: Consumption of Fish from the sinkhole		
Trichloroethylene	7E-05	
Selenium, dissolved	1E-05	
Carbon Tetrachloride	5E-05	
Tetrachloroethylene	4E-06	
Arsenic	2E-07	
Benzene	0E+00	
Styrene	1E-07	
1,2 Dichlorethane	0E+00	
1,4 Dichlorobenzene	0E+00	
2 Methylnapthalene	5E-06	
Lead	0E+00	
		1E-04
Exposure Pathway: Ingestion of shoreline sediments while playing in the sinkhole		
Selenium	2E-05	
Methylene chloride	3E-08	
4-Methylphenol	1E-05	
		3E-05
Recreational Adult - Total Future Hazard Quotient		
		1E-03

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4.10.5.2 Toxicity Assessment

RfDs developed by the EPA are generally considered to have uncertainty spanning an order of magnitude or more. Consequently, total exposure HIs for the resident child and adult may be estimated high or low by an order of magnitude or more.

Low confidence by EPA in an RfD value, such as low confidence in the Cr(VI) oral RfD, indicates high uncertainty in the accuracy of the toxicity value. High uncertainty indicates that the value may change in the future if additional toxicity data were to become available Conversely, high confidence by the EPA in an RfD indicates low uncertainty in the accuracy of the toxicity value.

SFs developed by the EPA are generally conservative and represent the upper bound limit of the probability of a cancer response. Thus, the actual cancer risk due to exposure to the chemicals of concern is likely to be lower than the estimated risk.

A second area of uncertainty is those chemicals which were not included in the quantitative assessment because of lack of carcinogenic or noncarcinogenic toxicity values. Chemicals lacking RfD values include lead, 1,4-dichlorobenzene, and 1,2-dichloroethane and those lacking SFs include selenium, 4-methylphenol, 2-methylnapthalene, lead, and styrene. The total risk without considering these chemicals is underestimated. Styrene has been classified as a probable human carcinogen and a SF will likely be developed in the future.

4.10.5.3 Risk Estimates

The uncertainties involved in combining pathways for the future land-use are considered minimal, as the dermal and ingestion pathways could reasonably contribute to exposure of the same individual over the same period of time. While assumption of dose accumulation ignores possible synergisms and antagonisms among chemicals, it does prevent the under-estimation of risks at the site.

4.10.6 Conclusions

No current pathways were quantitatively evaluated for Site 4. A summary of future carcinogenic and noncarcinogenic risks were presented previously in Tables 4-63 through 4-66.

Per MDNR guidance a cancer risk exceeding 1×10^{-6} is an unacceptable human health risk. No chemical-specific or pathway cancer risks are above 1×10^{-6} for the recreational adult or recreational child. Total exposure cancer risks are also below 1×10^{-6}. These results indicate an acceptable cancer risk exists for future recreational use of the sinkhole.

For noncarcinogenic effects, EPA guidance considers a HI greater than 1 to indicate potential for adverse noncarcinogenic health effects (EPA, 1989b). It has been demonstrated that the future HIs for the adult and child are below this reference level, indicating a low potential for adverse noncarcinogenic health effects.

Uncertainties in the risk assessment were evaluated in Section 4.10.5. The largest uncertainty for the Site 4 health assessment is the reasonable maximum exposure concentration modeled for chemicals entering the sinkhole. The maximum concentration entering the sinkhole was used as the reasonable maximum exposure concentration. In reality the concentrations of the chemicals entering the sinkhole will vary with time.

No data was collected regarding the deeper limestone aquifer. The potential for groundwater contaminants to migrate from the sinkhole and contaminate on-site or off-site drinking wells is qualitatively assessed. The sinkhole is hydraulically connected to the Traverse Group limestone aquifer and the potential exists for contaminants to migrate into the limestone aquifer. Groundwater beneath the facility contains class A and B carcinogens and could pose a health threat if exposure occurs.

4.11 SITE 5 - SECOND FIRE TRAINING AREA RISK ASSESSMENT

A baseline risk assessment was conducted for Site 5, Second Fire Training Area, to estimate the health risk for human receptors.

Section 4.11.1 identifies the chemicals of potential concern. Section 4.11.2 present an exposure assessment for human receptors. The toxicity assessment for chemicals of potential concern was previously presented in Section 4.4. The risk characterization for carcinogenic and noncarcinogenic effects is presented in Section 4.11.4. Uncertainties in the human health assessment are discussed in Section 4.11.5.

Section 4.11.6 presents a summary of total carcinogenic risk and the total exposure HIs for on-site adults and children.

4.11.1 Identification of Chemicals of Concern

Chemicals of potential concern at Site 5 were selected for groundwater and surface water through the process outlined in Section 4.2. The results of the selection process are presented in Section 4.11.1 through 4.11.2. The soils at Site 5 are part of a focused feasibility study and are not considered in this risk assessment.

4.11.1.1 Selection of Chemicals of Potential Concern in the Surface Water

No surface water data was obtained from Lake Winyah. Well SF5MW2 is located approximately 250 ft from Lake Winyah. Di-n-butyl phthalate was the only compound detected in this well. It was detected below acceptable MDLs and is not considered a chemical of potential concern (Table 4-67). Site 5 groundwater also discharges to the sinkhole, which is addressed in Section 4.10.

Chemicals of concern present in the shallow aquifer are considered future chemicals of potential concern for the surface water. These chemicals are listed in Section 4.11.1.2.

Table 4-67 Data Comparison Table: Surface Water, Well 2
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Detected Concentrations (µg/ℓ)	Acceptable Method Detection Limit (µg/ℓ)
Semi-volatiles (µg/ℓ)			
Di-n-butyl phthalate	1/1	0.7000	5

4.11.1.2 Selection of Chemicals of Potential Concern in the Shallow Aquifer

Table 3-16 presents a summary of the validated data collected during the RI. A complete data set is included in Appendix L. Data from three rounds of groundwater sampling prior to the RI are included in Appendix N and O but were not used in the estimate of risk due to the age of the data. Table 4-68 presents a summary of the range of detected concentrations, the number of detections, and the MDNR criteria used in the evaluation.

The chemicals listed below were detected at levels above the Act 307 Type B cleanup criteria and have been selected as chemicals of potential concern:

- 1,2-Dichloroethane
- 1,4-Dichlorobenzene
- Benzene
- Styrene.

4.11.2 Exposure Assessment

The purpose of the exposure assessment is to estimate the type and magnitude of human receptor exposure to chemicals of potential concern resulting from Site 5 activities. The following exposure assessment components are evaluated in this section:

- Characterization of the exposure setting (Section 4.11.2.1)
- Identification of exposure pathways/receptors (Section 4.11.2.2)
- Estimation of chemical concentrations at receptors (Section 4.11.2.3)
- Estimation of on-site child and adult intake values (Section 4.11.2.4).

4.11.2.1 Characterization of the Exposure Setting

Site 5 is located within the training area of the Alpena CRTC (Figure 1-8). The land surrounding and including Site 5 is used for combat training. The soils at Site 5 are scheduled to be remediated under a focused feasibility study and are not considered in this risk assessment. Lake Winyah lies approximately 305 m (1,000 ft) to the northwest of Site 5.

Table 4-68 Data Summary Table: Groundwater, Site 5-Second Fire Training Area
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (μg/l)	Act 307* Cleanup Criteria (μg/l)
Aromatic Volatiles (μg/l)			
1,2-Dichlorobenzene	1 / 9	4.7 / 4.7	600
1,2-Dimethylbenzene	2 / 9	0.13 / 0.88	280{R}
1,3-Dichlorobenzene	2 / 9	0.54 / 2.9	600
1,3-Dimethylbenzene	1 / 1	8 / 8	280{R}
1,4-Dichlorobenzene	1 / 9	3.5 / 3.5	1.5
Benzene	3 / 9	0.26 / 52	1.2
Chlorobenzene	1 / 9	0.41 / 0.41	130
Ethylbenzene	2 / 9	0.49 / 0.68	74{R}
Styrene	2 / 9	0.67 / 1.5	1.2
Toluene	1 / 9	0.24 / 0.24	790{R}
Halogenated Volatiles (μg/l)			
1,2-Dichloroethane	1 / 9	0.44 / 0.44	0.38
Methylene chloride	3 / 9	0.026 / 0.45	4.6
Trichloroethylene	2 / 9	0.21 / 0.63	2.2
Low Con. Semivolatiles (μg/l)			
2,4-Dimethylphenol	1 / 9	4 / 4	350
Di-n-butyl phthalate	4 / 9	0.5 / 0.7	840
Diethyl phthalate	3 / 9	0.5 / 1	5200
Dimethyl phthalate	1 / 9	0.6 / 0.6	70000
Phenol	2 / 9	2 / 4	4200
Metals (μg/l)[1)]			
Arsenic	4 / 9	4.3 / 20.5	
Chromium	2 / 9	9.8 / 81.7	
Copper	1 / 9	73.3 / 73.3	
Lead	2 / 9	6.5 / 44.1	
Nickel	1 / 9	69.9 / 69.9	
Selenium, Dissolved	1 / 9	7.3 / 7.3	35{C}
Zinc	2 / 9	33.1 / 259	
Zinc, Dissolved	4 / 9	6.8 / 83.5	2300{C}

* Refer to Table 4-1 for explanation of Act 307 footnotes.
1) Criteria are presented for dissolved metals only.

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This shoreline of Lake Winyah, west of Site 5, has minimal recreational use due to its steep bank and forested shoreline. Because of its poor access, this area of the lake is used sparingly as a fishing area by personnel stationed or training at the Alpena CRTC. The sinkhole at Site 4 is located approximately 533 m (1,750 ft) to the southeast of Site 5. No recreational activities occur at the sinkhole.

The shallow aquifer is present beneath Site 5 at approximately 1.8 m (6 ft) bgs. A groundwater mound exists west of Site 5. The direction of surficial groundwater flow is oriented radially away from the mound. Groundwater flows southeast towards the sinkhole at the southern end of the site and at the northern end of the site, groundwater flows to the northwest to Lake Winyah. Limestone bedrock is encountered at depths of approximately 6 to 7.6 m (20 to 25 ft) bgs. A discontinuous clay layer was observed above the limestone. In addition, the summer 1993 groundwater sampling results suggest that contaminated groundwater is moving vertically downward. The potential exists at Site 5 for contaminated groundwater contained within the shallow aquifer to migrate into the limestone. The direction of groundwater flow in the limestone aquifer is unknown since no bedrock wells were installed. However off-site bedrock residential wells exist to the north, south, and east of the Alpena CRTC.

The drinking water supply for the Alpena CRTC consists of on-base production wells, located south of Site 5. PW2 is screened in both the shallow and limestone aquifer and consequently, provides a conduit for migration of contaminants from the shallow aquifer into the limestone aquifer. Shallow groundwater flow at Site 5 is southeast and northwest, consequently, little potential exists for shallow groundwater at Site 5 to migrate to PW2.

4.11.2.2 Identification of Exposure Pathways/Receptors

The ANG holds the lease on the land until 2039; therefore, the current land-use has also been evaluated for future exposure. The Alpena CRTC currently utilizes the Site 5 area for combat readiness training. No full-time employees utilize the site. The site is used for combat training during the months of April through September for two-week training sessions. Families of personnel training at the facility visit on the weekends and use the recreational facilities at the CRTC. Lake Winyah is used only for fishing purposes in the area adjacent to Site 5.

An alternate future land-use which will be considered is recreational use of the land for fishing and hunting. Future residential land-use is deemed highly improbable due to the location of the land in a rural area with low growth.

The following potential current exposure pathways and receptors were identified:

- Ingestion of contaminated fish caught in Lake Winyah by adults and children
- Inhalation of vapor phase chemicals during groundwater use by off-site residents
- Ingestion of contaminated drinking water from bedrock wells by off-site residents

- Ingestion of contaminated drinking water from on-site production wells by facility personnel or visitors

- Inhalation of vapor phase chemicals during domestic groundwater use by facility personnel or visitors

- Dermal contact with groundwater during domestic use by facility personnel or visitors.

The following pathways and receptors were identified for future land-use scenarios:

- Future ingestion of contaminated fish caught in Lake Winyah by adults and children

- Future incidental ingestion of contaminated surface water by adults and children while playing or swimming in the sinkhole

- Future dermal absorption of contaminated surface water by adults and children playing in the sinkhole

- Receptors include recreational adult and child, on-site adult, and off-site adult and child

- Future inhalation of vapor phase chemicals during domestic groundwater use from down gradient bedrock wells by adults and children

- Future ingestion of contaminated drinking water from down gradient bedrock wells by adults and children

- Future dermal absorption of contaminated groundwater during domestic use from down gradient bedrock wells by adults and children

- Future ingestion of contaminated drinking water from future shallow groundwater wells

- Future inhalation of vapor phase chemicals during domestic groundwater use from future down gradient shallow wells by facility personnel

- Future dermal absorption of contaminated groundwater from future down gradient shallow wells by facility personnel.

Receptors include recreational adult and child, on-site adult, and off-site adult and child. Groundwater flows radially toward both the sinkhole and Lake Winyah. No contaminants were detected above acceptable MDLs in well SF5MW2 located 250 ft up gradient from Lake Winyah. These data indicate that the contaminant plume has not migrated to Lake Winyah; therefore, the current exposure pathway of ingestion of contaminated fish is considered incomplete and eliminated from further consideration.

The location of the groundwater divide at Site 5 fluctuates and the direction of groundwater flow at SF5MW2 may vary seasonally. Consequently, the current potential does exist for contaminants detected in the SF5MW2 to migrate to Lake Winyah. This pathway is retained for consideration.

Because the clay layer detected at Site 5 is discontinuous and therefore could not act as a sufficient aquitard and because the direction of groundwater flow in the limestone aquifer is unknown, current exposure pathways involving the deep aquifer are considered complete and are retained for consideration. These pathways are addressed qualitatively in Section 4.11.6. The on-site production wells are addressed in Section 4.7.

The shallow aquifer in the vicinity of Site 5 is considered incapable of sustaining a drinking water well, consequently, the following future potential exposure pathways are considered incomplete and are eliminated from further consideration:

- Ingestion of contaminated drinking water from future down gradient shallow wells
- Dermal absorption from contaminated shallow groundwater
- Inhalation of vapor phase chemicals during future shallow groundwater use.

Pathways involving the sinkhole are addressed in Section 4.10. Based on the elimination of all incomplete pathways, Table 4-69 presents the future exposure pathways which are considered complete and that are not addressed elsewhere in another site.

4.11.2.3 Estimation of Chemical Concentrations at Receptors

Current Exposure Concentration

No data exists on the off-site residential groundwater, consequently, these pathways are addressed qualitatively. Table 4-70 presents the average, minimum, maximum, and 95 percent UCL for the chemicals of concern.

Future Exposure Concentrations

Future concentrations of chemicals of potential concern in the shallow groundwater and surface water were predicted using a two-dimensional MOC solute transport model. The model estimated the maximum concentration of Site 5 chemicals of concern occurring in the sinkhole and Lake Winyah over time. Future pathways involving off-site residential groundwater are addressed qualitatively. Table 4-70 presents the modeled concentrations used in the exposure assessment. Details of the model are included in Appendix T.

4.11.2.4 Estimation of On-Site Child and Adult Intake Values

On-site child and adult CDI values for carcinogenic effects and subchronic noncarcinogenic effects were estimated for exposure pathways identified in Table 4-69. Table 4-71 presents

Table 4-69 Current and Future Exposure Pathways – Site 5
MIANG, Alpena, CRTC, Michigan

Receptor Population	Exposure Point	Exposure Pathway
Current Land-use		
Adult and Child	On-site/Off-site	Ingestion of contaminated bedrock aquifer groundwater
Future Land-use		
Adult and Child	On-site/Off-site	Future ingestion of contaminated groundwater
Adult and Child	On-site	Future ingestion of contaminated fish from Lake Winyah

the formulas and assumptions used to model future RME intake values for each identified exposure pathway. Standard default exposure factors were used to estimate intake where applicable; acceptable exposure factor references are listed for those standard default exposure factors. Reasonable assumptions were made to quantify site-specific exposure factors. Site-specific assumptions were necessary to estimate exposure frequencies for children. Children of visiting or full-time employees may use the on-site facilities during the weekends. It was assumed that children would be present on-site 6 months per year for 8 days per month for a total of 48 days per year. It was further assumed that these children would be present through the childhood years (0-15 years) for an exposure duration of 15 years. The exposure frequency of 48 days per year was assumed to be applicable for recreational land-use also.

Using the exposure intake models presented in Table 4-71, future chemical intake values were estimated for the potential receptors previously identified. Table 4-72 present a summary of the exposure assessment for current and future land-use at Site 5. Detailed calculations are presented in Appendix T.

4.11.3 Toxicity Assessments

Toxicity profiles for chemicals of potential concern were presented previously in Section 4.4.1, Toxicity Profiles. Section 4.4.2, Toxicity Values, presents the toxicity values for chemicals of potential concern.

4.11.4 Risk Characterization

The potential risks associated with the chemicals of concern were evaluated as outlined in Section 4.5. Section 4.11.4.1 presents the risk characterization for current land-use and Section 4.11.4.2 presents the future land-use risk characterization.

Table 4-70
Reasonable Maximum Exposure Concentrations - Site 5
MIANG, Alpena CRTC, Alpena, Michigan

Matrix	Compound	Units	Arithmetic Mean	N	Maximum Value	Minimum Value	95% UCL	Maximum Modeled Concentration	Year Maximum Occurs
GROUNDWATER	Styrene	ug/l	0.33833	9	1.5	0.125	0.63062		
GROUNDWATER	Benzene	ug/l	10.47889	9	52	0.175	23.25485		
GROUNDWATER	1,4-Dichlorobenzene	ug/l	0.50313	8	3.5	0.075	1.31443		
GROUNDWATER	1,2-Dichloroethane	ug/l	0.16	9	0.44	0.125	0.2251		
SURFACE WATER	Styrene	ug/l						0.01	20
SURFACE WATER	Benzene	ug/l						1.5	20
SURFACE WATER	1,4-Dichlorobenzene	ug/l						0.1	20
SURFACE WATER	1,2-Dichloroethane	ug/l						0.01	20

Table 4-71 Model for Estimating Future Chemical Intake by Adults and Children through Consumption of Fish Caught in Lake Winyah - Site 5 MIANG, Alpena CRTC, Alpena, Michigan

$$CDI\ (mg/kg\text{-}day) = \frac{CF \times IR \times FI \times EF \times ED}{BW \times AT}$$

where:

CDI	=	Chronic Daily Intake (mg/kg-day), representing the RME.
CF	=	Chemical Concentration in Fish
IR	=	Inhalation Rate (m^3/hour)
FI	=	The Fraction of total Figh Ingested which is caught from Thunderbay River (unitless).
EF	=	Exposure Frequency (days/year)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Adult	Child
Chemical Concentration in Fish[5]		
Ingestion Rate (kg/day)	0.054[1]	0.043[2]
Fraction of fish ingested (unitless)	0.50[3]	0.50[3]
Exposure Frequency (days/yr)	26[3]	26[3]
Exposure Duration (year)	25[1]	15[3]
Body Weight (kg)	70[1]	27[4]
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) U.S. Environmental Protection Agency, 1991.
2) Pao, Eleonore, M., 1982.
3) Site specific assumption – EF = 1 day/wk for 26 weeks.
4) U.S. Environmental Protection Agency, 1989a.
5) The chemical concentration in fish is equal to the chemical concentration in surface water x fish bioconcentration factor (BCF). The following BCFs were applied di-n-butyl phthalate 1.1E^4 (MEPAS), Styrene 1.0 E^2 (MEPAS), Benzene (2.4 E^1), 1,4 dichlorobenzene (6 x E^1). (EPA, 1980a), 1,2 dichloroethane 2 (EPA 1980b).

TABLE 4-72
Exposure Assessment- Future Land Use - Site 5
MIANG, Alpena CRTC, Alpena, Michigan

Population	Exposure Pathway	Chemical	Chronic Daily Intakes (CDI)(mg/kg-day) Carcinogenic Effects	Noncarcinogenic Effects
On-site/Recreational Adult	Consumption of Fish from Thunderbay River	Styrene	9.81E-09	2.748E-08
		Benzene	3.533E-07	9.891E-07
		1,4-Dichlorobenzene	5.888E-08	1.649E-07
		1,2-Dichloroethane	1.963E-07	5.495E-07
Recreational Child	Consumption of Fish from Thunderbay River	Styrene	1.215E-08	5.672E-08
		Benzene	4.376E-07	2.042E-06
		1,4-Dichlorobenzene	7.293E-08	3.403E-07
		1,2-Dichloroethane	2.431E-07	1.134E-06

4.11.4.1 Current Land-Use Conditions

No current pathways were quantitatively evaluated. Risk to off-site receptors is qualitatively discussed in Section 4.11.6.

4.11.4.2 Future Land-Use Conditions

Tables 4-73 and 4-74 present cancer risk estimates for the future recreational child and adult, respectively. Detailed calculations are presented in Appendix T. Each table presents chemical-specific cancer risks, pathway cancer risks, and total exposure cancer risk for the future child and adult.

Table 4-75 and 4-76 present chronic HI estimates for the future recreational child and adult, respectively. Detailed calculations are presented in Appendix T. Each table presents chemical-specific HIs, pathway HIs, and total exposure HIs for the future child and adult.

Future consumption of contaminated fish from Lake Winyah is the only potentially complete future pathway at Site 5. Total pathway cancer risks for the future adult and child were below the 1×10^{-6} reference level, indicating an acceptable level of risk.

The noncarcinogenic HI estimators for the future adult and child indicate risks below the reference level of 1, indicating low potential for adverse noncarcinogenic health effects.

4.11.5 Risk Assessment Uncertainties

This section presents a discussion of uncertainties involved in the process of quantifying risk for human receptors. Uncertainties involved in the exposure assessment and toxicity assessment are discussed separately.

4.11.5.1 Exposure Assessment Uncertainties

Uncertainty in the exposure assessment is a function of the completeness of site data, assumptions that simplify and approximate actual current or future site conditions, and professional judgement used in developing and evaluating various parameters. Assumptions and inferences must be made to develop exposure scenarios. These assumptions and inferences introduce uncertainties into the exposure assessment.

95 percent UCLs for sediment were calculated based on three samples collected from the toe of the landfill. It was noted that the sediment contained asphalt-like particles. It is likely that the concentration of PAHs detected in these sediments is overestimated and would be significantly lower further away from the toe of the landfill.

The exposure scenarios presented are conservative, and overestimate rather than underestimate exposure. The approach is conservative and is designed to compensate for uncertainties inherent in the exposure assessment. The use of very conservative health-protective exposure factors in the exposure assessment process results in final intake values

Table 4-73
Future Carcinogenic Risk Estimates for the Recreational Child - Site 5
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Consumption of Fish fromThunderbay River			
Styrene	0E+00		
Benzene	1E-08		
1,4-Dichlorobenzene	2E-09		
1,2-Dichloroethane	3E-08		
		5E-08	
Recreational Child - Total Cancer Risk			
			5E-08

Table 4-74
Future Carcinogenic Risk Estimates for the On-Site/Recreational Adult - Site 5
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Consumption of Fish fromThunderbay River			
Styrene	0E+00		
Benzene	1E-08		
1,4-Dichlorobenzene	2E-09		
1,2-Dichloroethane	3E-08		
		4E-08	
On-Site/Recreational Adult - Total Cancer Risk			
			4E-08

SITE5/ 5CSUM.WB1/ 940127

Table 4-75
Estimate of Future Noncarcinogenic Effects for the Recreational Child - Site 5
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Consumption of Fish fromThunderbay River			
Styrene	3E-07		
Benzene	0E+00		
1,4-Dichlorobenzene	0E+00		
1,2-Dichloroethane	0E+00		
		3E-07	
Recreational Child - Total Hazard Index			
			3E-07

Table 4-76
Estimate of Future Noncarcinogenic Effects for the On-Site/Recreational Adult - Site 5
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Consumption of Fish fromThunderbay River			
Styrene	1E-07		
Benzene	0E+00		
1,4-Dichlorobenzene	0E+00		
1,2-Dichloroethane	0E+00		
		1E-07	
On-Site/Recreational Adult - Total Hazard Index			
			1E-07

that are extremely conservative. RME chronic intake values may be overestimated by one to two orders of magnitude.

In quantifying exposure levels, the chemicals are assumed to be uniformly distributed over the defined area, thus resulting in a uniform exposure level. Chemical analytical data were obtained from a directed sampling program, i.e., sampling locations were generally selected on the basis of where contaminants were expected to be present. Sampling zones found to be free of contamination received less investigation. This sampling scheme tends to greatly overestimate the overall chemical concentrations at a site.

One of the assumptions used in the exposure assessment is that the current chemical concentrations in groundwater and future modeled chemical concentrations are assumed to remain constant over exposure pathway duration and that the transport mechanisms are assumed to have reached equilibrium. This means that the levels will not decrease due to the exhaustion of the contaminant sources over the assumed exposure periods. The result of this assumption is a probable overestimation of surface water exposure point concentrations because contaminant sources will not likely remain constant over time.

Finally, the assumption is made that human exposure remains constant over the lifetime of an individual. In actuality, lifestyle changes due to age and actual residence time will alter the projected exposure durations. Movement of individuals in and out of the potentially exposed community also affects exposure duration.

4.11.5.2 Toxicity Assessment

RfDs developed by the EPA are generally considered to have uncertainty spanning an order of magnitude or more. Consequently, total exposure HIs for the resident child and adult may be estimated high or low by an order of magnitude or more.

Low confidence by EPA in an RfD value, such as low confidence in the Cr(VI) oral RfD, indicates high uncertainty in the accuracy of the toxicity value. High uncertainty indicates that the value may change in the future if additional toxicity data were to become available. Conversely, high confidence by the EPA in an RfD indicates low uncertainty in the accuracy of the toxicity value.

SFs developed by the EPA are generally conservative and represent the upper bound limit of the probability of a cancer response. Thus, the actual cancer risk due to exposure to the chemicals of concern is likely to be lower than the estimated risk.

A second area of uncertainty is those chemicals which were not included in the quantitative assessment because of lack of carcinogenic or noncarcinogenic toxicity values. Chemicals lacking RfD values include benzene, 1,4-dichlorobenzene, and 1,2-dichloroethane and those lacking SFs include di-n-butyl phthalate and styrene. The total risk without considering these chemicals is underestimated. Styrene has been classified as a probable human carcinogen and a SF will likely be developed in the future.

4.11.6 Conclusions

No pathways are complete for the current land-use scenario. A summary of future carcinogenic and noncarcinogenic risks was presented previously in Tables 4-77 through 4-80.

Per MDNR guidance a cancer risk exceeding 1×10^{-6} is an unacceptable human health risk. It has been demonstrated that the future carcinogenic risks to the adult and child are below 1×10^{-6}. These total exposure risks indicate an acceptable carcinogenic risk for Site 5.

For noncarcinogenic effects, EPA guidance considers a HI greater than 1 to indicate potential for adverse noncarcinogenic health effects (EPA, 1989b). It has been demonstrated that the current and future HIs for the adult and child are below the reference level of 1 indicating a low potential for adverse noncarcinogenic health effects.

No data is available regarding the deeper limestone aquifer. The potential for groundwater contaminants to migrate to the deeper aquifer and contaminant on-site or off-site drinking wells was qualitatively assessed. No continuous clay layer which could act as an aquitard was detected at Site 5, consequently, the potential exists for contaminants to migrate vertically into the limestone aquifer. Contaminants currently present in the shallow aquifer include class A and B carcinogenic compounds which could pose a health threat if exposure occurs.

4.12 SITE 6 FORMER LANDFILL AND SITE 7 FIRST FIRE TRAINING AREA RISK ASSESSMENT

A baseline risk assessment was conducted for the Site 6/7 Former Landfill/First Fire Training Area to estimate the health risk for human receptors.

Section 4.12.1 identifies the chemicals of potential concern. Section 4.12.2 present an exposure assessment for human receptors. The toxicity assessment for chemicals of potential concern was previously presented in Section 4.6. The risk characterized for carcinogenic and noncarcinogenic effects is presented in Section 4.12.4. Uncertainties in the human health assessment are discussed in Section 4.12.5. Section 4.12.6 presents a summary of total carcinogenic risk and the total exposure HIs for on-site adult and child.

4.12.1 Identification of Chemicals of Potential Concern

Chemicals of potential concern at Site 6/7 were selected for groundwater, surface water, and sediments through the process outlined in Section 4.2. Soil sampling during the SI indicated no chemicals of potential concern above Act 307 Type A cleanup criteria. The few occurrences of elevated levels of lead, selenium, and zinc occurring in the landfill are considered to be outliers not associated with past fire training or waste disposal activities and are not considered further in this evaluation.

4.12.1.1 Selection of Chemicals of Potential Concern with the Shallow Aquifer

Table 3-18 presents a summary of the validated data collected during the RI. The complete data set is included in Appendix L. Table 4-77 presents a summary of the range of detected concentrations, the number of detected concentrations, and the MDNR criteria used during the evaluation. Data collected previous to the RI is included in Appendix N and O but was not used to estimate risk.
Carbon Tetrachloride was detected at levels above the MDNR Type B cleanup criteria and has been selected as a chemical of potential concern.

Dibromochloromethane and bromodichloromethane were detected above MDNR levels in sample duplicates but were non-detect in the corresponding sample. The results were averaged and the resulting concentrations were below MDNR Type B criteria, consequently, the compounds were not selected as chemicals of concern.

4.12.1.2 Selection of Chemicals of Potential Concern in the Surface Water

Groundwater in the shallow aquifer at Site 6/7 discharges to either the sinkhole at Site 4 or the backwater area of Lake Winyah. The sinkhole is addressed in Section 4.10. No surface water samples were taken in the backwater area of Lake Winyah. The data from Well LF6MW9, located at the edge of the landfill, adjacent to the backwater area of Lake Winyah is included in Table 3-17. Any contaminants detected in the groundwater from LF6MW9 will enter the backwater area. Table 4-78 presents the range of detected concentrations used in the evaluation. Filtered metals were used in the evaluation. The data indicates no compounds were detected above acceptable method detection limits, indicating the contaminants in the groundwater at Site 6/7 have not migrated to the backwater area of Lake Winyah. Therefore, no chemicals of concern were identified for surface water at Site 6/7.

4.12.1.3 Selection of Chemicals of Concern within Sediments

Sediments are a potential exposure point at two locations: the sinkhole at Site 4 and the backwater area of Lake Winyah. The sinkhole is addressed in Section 4.10. Table 3-17 presents a summary of the validated data collected at the backwater area during the RI. The complete data set is included in Appendix L. Table 4-79 presents a summary of the range of detected concentrations and the number of detected concentrations. No MDNR criteria exists for sediments, therefore the data was evaluated as described in Section 4.2.

The chemicals listed below were detected at elevated levels within the sediment in the backwater area of Lake Winyah and have been selected as chemicals of potential concern:

- Anthracene
- Benzo (a) anthracene
- Benzo (a) pyrene
- Benzo (b) fluoranthene

Table 4-77 Data Summary Table: Groundwater, Site 6/7-Former Solid Waste Landfill and First Fire Training Area MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (μg/l)	Act 307* Cleanup Criteria (μg/l)
Aromatic Volatiles (μg/l)			
1,2-Dimethylbenzene	1 / 9	0.26 / 0.26	280{R}
1,3-Dimethylbenzene	1 / 1	1.7 / 1.7	280{R}
Benzene	1 / 9	0.072 / 0.072	1.2
Chlorobenzene	1 / 9	0.17 / 0.17	130
Ethylbenzene	3 / 9	0.16 / 4.7	74{R}
Toluene	1 / 9	0.24 / 0.24	790{R}
Halogenated Volatiles (μg/l)			
1,1,1-Trichloroethane	1 / 9	0.3 / 0.3	200
1,2-Dichloropropane	1 / 9	0.25 / 0.25	0.52
Carbon Tetrachloride	1 / 9	1.1 / 1.1	0.27
Chloroform	1 / 9	0.14 / 0.14	5.6
Methylene chloride	2 / 9	0.027 / 0.075	4.6
Trichloroethylene	1 / 9	1.7 / 1.7	2.2
Low Con. Semivolatiles (μg/l)			
Butyl benzyl phthalate	1 / 9	2 / 2	1100
Di-n-butyl phthalate	2 / 9	1 / 1	840
Diethyl phthalate	5 / 9	0.6 / 2	5200
Phenol	3 / 9	2 / 3	4200
Metals (μg/l)[1)]			
Antimony	1 / 9	39.2 / 39.2	
Arsenic	3 / 9	8.2 / 13.4	
Beryllium	2 / 9	1.8 / 2.4	
Cadmium	2 / 9	5.4 / 5.5	
Chromium	3 / 9	60.5 / 75.9	
Copper	3 / 9	44.4 / 57.8	
Copper, Dissolved	2 / 9	8.2 / 8.9	1000{R}
Lead	4 / 9	2.1 / 127	
Mercury	1 / 9	0.36 / 0.36	

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Table 4-77 Data Summary Table: Groundwater, Site 6/7-Former Solid Waste Landfill and First Fire Training Area MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/l)	Act 307* Cleanup Criteria (µg/l)
Nickel	3 / 9	37.1 / 46.8	
Selenium	1 / 9	77.1 / 77.1	
Zinc	3 / 9	123 / 258	
Zinc, Dissolved	2 / 9	4.7 / 4.8	2300{C}

* Refer to Table 4-1 for explanation of Act 307 footnotes.

[1]Criteria are presented for dissolved metals only.

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Table 4-78 Data Summary Table: Surface Water, (based on LF6MW9) Site 6/7
MIANG, Alpena CRTC, Alpena, Michigan

Analyte	Frequency of Detection	Range of Detected Concentrations (µg/l)	Acceptable Method Detection Limits (µg/l)
Semivolatiles (ppb)			
Di-n-butyl phthalate	1 / 1	1.0000	5
Diethyl phthalate	1 / 1	1.0000	5
Phenol	1 / 1	3.0000	5
Metals (ppb)			
Zinc, Dissolved	1 / 1	4.7000	20

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Table 4-79 Data Summary Table: Sediment, Site 6/7 - Former Solid Waste Landfill and First Fire Training Area
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/kg)	Range of Background Concentrations (µg/kg)
Semivolatiles (ppb)			
Anthracene	1 / 4	460 / 460	ND
Benzo(a)anthracene	1 / 4	450 / 450	ND
Benzo(a)pyrene	1 / 4	320 / 320	ND
Benzo(b)fluoranthene	1 / 4	690 / 690	ND
Benzo(ghi)perylene	1 / 4	61 / 61	ND
Benzo(k)fluoranthene	1 / 4	690 / 690	ND
Butyl benzyl phthalate	3 / 4	55 / 510	ND
Carbazole	1 / 4	88 / 88	ND
Chrysene	1 / 4	430 / 430	ND
Di-n-butyl phthalate	1 / 4	64 / 64	ND
Fluoranthene	2 / 4	540 / 650	ND
Indeno(1,2,3-c,d)pyrene	1 / 4	120 / 120	ND
Phenanthrene	2 / 4	310 / 460	ND
Pyrene	2 / 4	290 / 420	ND
Metals (ppb)			
Chromium	4 / 4	4900 / 15900	18000
Copper	4 / 4	6200 / 16400	32000
Lead	4 / 4	5300 / 177000	11000
Nickel	1 / 4	7900 / 7900	21000
Selenium	1 / 4	2300 / 2300	2300
TPH (ppb)			
Total Petroleum Hydrocarbons	4 / 4	93400 / 994000	ND

ND - Not Determined

wp/t4-79.775-06/15/95

- Benzo (ghl) perylene
- Benzo (k) fluoranthene
- Butyl benzyl phthalate
- Carbazole
- Chrysene
- Di-n-butyl phthalate
- Fluoranthene
- Indeno (1,2,3-c,d) pyrene
- Lead
- Phenanthrene
- Pyrene
- Selenium.

4.12.2 Exposure Assessment

The purpose of the exposure assessment is to estimate the type and magnitude of human receptor exposure to chemicals of potential concern resulting from Site 6/7 activities. The following exposure assessment components are evaluated in this section:

- Characterization of the exposure setting (Section 4.12.2.1)
- Identification of exposure pathways/receptors (Section 4.12.2.2)
- Estimation of chemical concentrations at receptors (Section 4.12.2.3)
- Estimation of on-site child and adult intake values (Section 4.12.2.4).

4.12.2.1 Characterization of the Exposure Setting

Site 6/7 lies within the training area of the Alpena CRTC (Figure 1-9). Site 6 is an abandoned landfill which is primarily covered with grass and gravel. Site 7 is located on the road adjacent to Site 6. The road is covered with sand and gravel. Directly west of Site 6/7 is the backwater area of Lake Winyah. The facility wastewater treatment plant lies to the south of the site. Areas to the north and east are heavily forested.

The subsurface materials at Site 6 consist primarily of a 3-m (10-foot) thick zone of medium-grained quartz sand. A massive zone of sandy clay underlies the quartz sand over most of the site. In the area of MW4 and MW10, the natural stratigraphy has been replaced by fill material. In the area around MW5 and MW8, several discontinuous lenses of sand and clay were encountered. This material then grades back into the sandy clay material seen throughout the site. No clay layer sufficiently thick to be considered an aquitard was encountered between the shallow aquifer and the limestone aquifer at location LF6MW6.

The shallow aquifer beneath Site 6/7 exists at depths between 3 to 5.8 m (10 to 19 ft) bgs. A groundwater divide exists across Site 6 which separates water flowing southeast to the sinkhole from water flowing northwest into the backwater area of Lake Winyah and the Thunder Bay River. Water in the backwater area appears to be relatively stagnant. The shallow aquifer at Site 6/7 likely does not contain a sufficient quantity of water to support drinking water wells.

Drinking water wells present at Alpena CRTC are located southeast of Site 6/7. Off-site residential wells are located to the north, south, and east of the Alpena CRTC. These wells are screened in the limestone aquifer. No data on the limestone aquifer were collected during the RI.

4.12.2.2 Identification of Exposure Pathways/Receptors

The ANG holds the lease on the land until 2039; therefore, the current land-use has been evaluated for future exposure. No full-time employees are located at the site. The nearest location to a daily population is the wastewater treatment plant located adjacent to the site. Training activities take place on the Site 6/7 area from the months of April through September for two-week training sessions. Families of training personnel visit during the weekends and use the recreational facilities. The backwater area of Lake Winyah cannot support recreational activity and activity is minimal for that portion of Thunder Bay River. Recreational activity does not occur at the sinkhole.

The following potential current exposure pathways and receptors were identified:

- Ingestion of contaminated fish caught in the Thunder Bay River by adults and children
- Dermal contact with sediments in the backwater area of Lake Winyah by facility personnel
- Ingestion of sediments in the backwater area of Lake Winyah by facility personnel
- Incidental ingestion of contaminated surface water by adults and children playing in Thunder Bay River
- Dermal absorption of contaminated groundwater during domestic use by on-site personnel or off-site residents

- Ingestion of contaminated drinking water from down gradient bedrock wells by on-site personnel or off-site residents

- Inhalation of vapor phase chemicals during domestic groundwater use by on-site or off-site residents.

Receptors include recreational adults and children, on-site adults, and off-site residents.

The following potential future exposure pathways and receptors were identified:

- Future dermal absorption of contaminated surface water by adults and children playing in the sinkhole or in the Thunder Bay River

- Future ingestion of contaminated fish caught in the sinkhole by adults and children

- Future dermal contact with sediments in the backwater area of Lake Winyah by facility personnel

- Future ingestion of sediments in the backwater area of Lake Winyah by adults and children

- Future ingestion of contaminated fish caught in the Thunder Bay River by adults and children

- Future ingestion of contaminated drinking water from down gradient bedrock wells by on-site or off-site residents

- Future dermal absorption of contaminated groundwater during domestic use by on-site personnel or off-site residents

- Future inhalation of vapor phase chemicals during domestic groundwater use by on-site or off-site residents.

Receptors include recreational adults and children, on-site adults, and off-site residents.

Because no chemicals of concern were identified at the GSI, the following potential current exposure pathways are considered incomplete and eliminated from further consideration:

- Incidental ingestion of contaminated surface water at Thunder Bay River

- Dermal absorption of contaminated surface water from Thunder Bay River

- Ingestion of contaminated fish from Thunder Bay River.

No activity currently takes place in the backwater area of Lake Winyah, therefore the dermal contact pathway and the ingestion pathway are incomplete and are also eliminated from further consideration.

Because the clay layer detected at Site 6/7 is discontinuous and could not act as a sufficient aquitard, and because the direction of groundwater flow in the limestone aquifer is unknown, exposure pathways involving bedrock wells are considered complete and are retained for consideration. The future potential pathways involving the sinkhole are addressed in Section 4.10. Pathways involving on-site production wells are addressed in Section 4.7. Based on the elimination of all incomplete pathways, Table 4-80 presents the current and future exposure pathways which are considered complete and are addressed in this section.

4.12.2.3 Estimation of Chemical Concentrations at Receptors

The 95 percent UCL of the arithmetic mean, as outlined in Section 4.2, was calculated as the chemical exposure concentration for the future sediment exposure in backwater of Lake Winyah.

No data currently exists for off-site residential well water; therefore, these pathways will be addressed qualitatively in Section 4.12.6. Table 4-81 presents the 95 percent UCLs.

Future concentrations of chemicals of potential concern in surface water were predicted using a two-dimensional MOC solute transport. The model estimates the maximum concentration of Site 6/7 chemicals of concern occurring in the sinkhole and Thunder Bay River over time. Future pathways involving off-site residential groundwater are addressed qualitatively. Table 4-81 presents the modeled future concentrations for chemical of concern. Details of the model are included in Appendix U.

4.12.2.4 Estimation of On-site Child and Adult Intake Values

On-site child and adult CDI values for carcinogenic effects and subchronic noncarcinogenic effects were estimated for exposure pathways identified in Table 4-80. Tables 4-82 through 4-85 present the formulas and assumptions used to model current and future RME intake values for each identified exposure pathway. Standard default exposure factors were used to estimate intake where applicable; acceptable exposure factor references are listed for those standard default exposure factors. Reasonable assumptions were made to quantify site-specific exposure factors. Site-specific assumptions were necessary to estimate exposure frequencies for children. Children of visiting or full-time employees may use the on-site facilities during the weekends. It was assumed that children would be present on-site 6 months per year for 8 days per month for a total of 48 days per year. It was further assumed that these children would be present through the childhood years (0-15 years) for an exposure duration of 15 years. The exposure frequency of 48 days per year was also assumed for recreational land-use. It was assumed as a worst case scenario that the on-site adult and recreational adult are the same person. The on-site adult is present 250 days per year for work and another 48 days for recreation.

Using the exposure intake models presented in Tables 4-82 through 4-85, current and future chemical intake values were estimated for the potential receptors previously identified. Table 4-86 presents a summary of the exposure assessment for current and future land-use at Site 6/7. Detailed calculations are presented in Appendix U.

Table 4-80 Current and Future Exposure Pathways – Site 6/7
MIANG, Alpena, CRTC, Michigan

Receptor Population	Exposure Point	Exposure Pathway
Current Land-use		
Adult and Child	on-site/off-site	Ingestion of contaminated groundwater from bedrock wells
Future Land-use		
Adult and Child	on-site	Future dermal contact with sediment in backwater area of Lake Winyah
Adult and Child	on-site	Future ingestion of sediments in backwater area of Lake Winyah
Adult and Child	on-site	Future ingestion of contaminated fish caught in the Thunder Bay River or sinkhole
Adult and Child	on-site	Future incidental ingestion of contaminated surface water from Thunder Bay River or the sinkhole
Adult and Child	on-site	Future dermal absorption of contaminated surface water from Thunder Bay River or sinkhole
Adult and Child	off-site	Future ingestion of contaminated groundwater from bedrock wells
Adult and Child	off-site	Future dermal absorption of contaminated groundwater from bedrock wells
Adult and Child	off-site	Future dermal absorption of vapor contaminated phase chemicals from bedrock wells

4.12.3 Toxicity Assessments

Toxicity profiles for chemicals of potential concern were presented previously in Section 4.4.1, Toxicity Profiles. Section 4.4.2, Toxicity Values, presents the toxicity values for chemicals of potential concern.

4.12.4 Risk Characterization

The potential risks associated with the chemicals of concern were evaluated as outlined in Section 4.5. Section 4.12.4.1 presents the risk characterization for current land-use and Section 4.12.4.2 presents the future land-use risk characterization. The USEPA has proposed the use of relative potency factors for assessment of risk from oral and dermal exposure to potentially carcinogenic PAHs. To determine carcinogenic risk for ingestion and dermal absorption of chemicals in sediment, the final risk estimates for PAHs were obtained by applying the appropriate potency factor as listed in Appendix U.

Table 4-81
Reasonable Maximum Exposure Concentrations, Site 6/7
MIANG, Alpena CRTC, Alpena, MI

Matrix	Compound	Units	Average Value	N	Maximum Value	Minimum Value	95% UCL	Maximum Future Modeled Concentration	Year Maximum Occurs
GROUNDWATER	Carbon Tetrachloride	ug/l	0.28	9	1.1	0.175	0.469		
SEDIMENT	Anthracene	ug/kg	682.67	3	1150.00	348.00	1385.90		
SEDIMENT	Benzo(a)anthracene	ug/kg	681.00	3	1150.00	343.00	1387.62		
SEDIMENT	Benzo(a)pyrene	ug/kg	659.33	3	1150.00	278.00	1411.50		
SEDIMENT	Benzo(b)fluoranthene	ug/kg	720.67	3	1150.00	462.00	1351.87		
SEDIMENT	Benzo(ghi)perylene	ug/kg	616.00	3	1150.00	148.00	1466.10		
SEDIMENT	Benzo(k)fluoranthene	ug/kg	720.67	3	1150.00	462.00	1351.87		
SEDIMENT	Butyl benzyl phthalate	ug/kg	373.33	3	550.00	60.00	832.04		
SEDIMENT	Carbazole	ug/kg	620.67	3	1150.00	162.00	1459.85		
SEDIMENT	Chrysene	ug/kg	677.33	3	1150.00	332.00	1391.47		
SEDIMENT	Di-n-butyl phthalate	ug/kg	616.67	3	1150.00	150.00	1465.20		
SEDIMENT	Fluoranthene	ug/kg	510.67	3	550.00	442.00	611.27		
SEDIMENT	Indeno(1,2,3-c,d)pyrene	ug/kg	626.00	3	1150.00	178.00	1452.81		
SEDIMENT	Lead	mg/kg	74.37	3	177.00	5.30	227.17		
SEDIMENT	Phenanthrene	ug/kg	402.67	3	550.00	310.00	620.15		
SEDIMENT	Pyrene	ug/kg	389.33	3	550.00	290.00	626.08		
SEDIMENT	Selenium	mg/kg	1.00	3	2.30	0.22	2.91		
SURFACE WATER	Carbon Tetrachloride	ug/l						0.01	20

If the 95% UCL is greater than the maximum value, then the maximum value is the reasonable maximum exposure concentration.

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Table 4-82 Model for Estimating Current and Future Chemical Absorbed Dose by Adults and Children through Dermal Contact with Sediments in Backwater Area of Lake Winyah - Site 6/7 MIANG, Alpena CRTC, Alpena, Michigan

$$\textit{Absorbed Dose (mg/kg-day)} = \frac{CS \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

where:

CS	=	Chemical Concentration in Soil (mg/kg)
CF	=	Conversion Factor (10^{-6} kg/mg)
SA	=	Skin Surface Area Available for Contact (cm^2/event)
AF	=	Soil to Skin Adherence Factor (mg/cm^2)
ABS	=	Absorption Factor (unitless)
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Child	Adult
Surface area (cm^2/day)	1,490[1]	3,120[1]
Soil to Skin Adherence Factor (mg/cm^2)	2.77[7]	2.77[1]
Absorption Factor	0.01 0.25	0.01 metals[2] 0.25 organics
Exposure Frequency (days/yr)	48	48
Exposure Duration (years)	15	25[2]
Body Weight (kg)	27	70[3]
Averaging Time (years), (noncarcinogenic)	15	25

Notes:
1) U.S. Environmental Protection Agency, 1989b - Average of arms and hands
2) estimate
3) U.S. Environmental Protection Agency, 1991.

Table 4-83 Model for Estimating Future Intake by Adults and Children through Ingestion of Surface Water while Swimming or Playing in Thunderbay River - Site 6/7 MIANG, Alpena CRTC, Alpena, Michigan

$$CDI\ (mg/kg\text{-}day) = \frac{CW \times CR \times ET \times EF \times ED}{BW \times AT}$$

where:

CDI	=	Chronic Daily Intake (mg/kg-day), representing the RME.
CW	=	Chemical Concentration in Surface Water (mg/ℓ).
CR	=	Surface Water Contact Rate (ℓ/hour).
ET	=	Exposure Time (hours/day).
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Adult	Child
Surface Water Contact Rate ml/hr	50[1]	50[1]
Exposure Time (hours/day)	2.6[2]	2.6[2]
Exposure Frequency (days/yr)	48[3]	48[3]
Exposure Duration (years)	25[3]	15[3]
Body Weight (kg)	70[1]	27[1]
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) U.S. Environmental Protection Agency, 1989b.
2) U.S. Environmental Protection Agency, 1989a.
3) Site specific assumption – Section 4.7.2.4.

Table 4-84 Model for Estimating Future Chemical Absorbed Dose by Adults and Children through Dermal Contact with Chemicals in Thunder Bay River - Site 6/7 MIANG, Alpena CRTC, Alpena, Michigan

$$Absorbed\ Dose\ (mg/kg\text{-}day) = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

where:

CW	=	Chemical Concentration in Water (mg/ℓ).
SA	=	Skin Surface Area Available for Contact (cm^2).
PC	=	Chemical-specific Dermal Permeability Constant (cm/hr) default 8.4×10^{-4}
ET	=	Exposure Time (hours/day).
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
CF	=	Volumetric Conversion Factor for Water (1 liter/1000 cm^3)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Adult	Child
Skin Surface Area (cm^2)	19,400[1]	13,300[1]
Dermal Permeability Constant (cm/hr)[4]	8.4×10^{-4} [2]	8.4×10^{-4} [2]
Exposure Time (hours/day)	2.6[2]	2.6[2]
Exposure Frequency (days/yr)	48[3]	48[3]
Exposure Duration (years)	25	15[3]
Body Weight (kg)	70	27[2]
Averaging Time (years), (noncarcinogenic)	25	15

Notes:

1) U.S. Environmental Protection Agency, 1989b - Child is average for ages 0-15.
2) U.S. Environmental Protection Agency, 1989.
3) Site specific assumption
4) Chemical-specific permeability constants were used where available. Carbon tetrachloride = 2.2×10^{-2} (Table 5-7 U.S. EPA, 1992a)

Table 4-85 Model for Estimating Future Chemical Intake by Adults and Children through Consumption of Fish Caught in Thunderbay River - Site 6/7 MIANG, Alpena CRTC, Alpena, Michigan

$$CDI\ (mg/kg\text{-}day) = \frac{CF \times IR \times FI \times EF \times ED}{BW \times AT}$$

where:

CDI	=	Chronic Daily Intake (mg/kg-day), representing the RME.
IR	=	Inhalation Rate (m^3/hour)
FI	=	The Fraction of total Figh Ingested which is caught from Thunderbay River (unitless).
EF	=	Exposure Frequency (days/year)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Adult	Child
Chemical Concentration in Fish[4]		
Ingestion Rate (kg/day)	0.054[1]	0.043[2]
Fraction of fish ingested (unitless)	0.50[3]	0.50[3]
Exposure Frequency (days/yr)	26[3]	26[3]
Exposure Duration (years)	25[1]	15[3]
Body Weight (kg)	70[1]	27[4]
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) U.S. Environmental Protection Agency, 1991.
2) Pao, Eleonore, M., 1982.
3) Site specific assumption - EF = 1 day/wk for 26 weeks.
4) The chemical concentration in fish is equal to the chemical concentration in surface water x fish bioconcentration factors (BCFs). The following BCFs were applied: Carbon tetrachloride 1.7 (EPA, 1980c)

Table 4-86
Future Exposure Assessment - Site 6/7
MIANG, Alpena CRTC, Alpena, Michigan

Population	Exposure Pathway	Chemical	Chronic Daily Intake (CDI)(mg/kg-day) Carcinogenic Effects	Noncarcinogenic Effects
Recreational Adult	Dermal contact with sediment from the backwater area of Lake Winyah	Anthracene	1.7E-06	4.7E-06
		Benzo(a)anthracene	1.7E-06	4.7E-06
		Benzo(a)pyrene	1.7E-06	4.7E-06
		Benzo(b)fluoranthene	1.7E-06	4.7E-06
		Benzo(ghi)perylene	1.7E-06	4.7E-06
		Benzo(k)fluoranthene	1.7E-06	4.7E-06
		Butyl benzyl phthalate	7.8E-07	2.2E-06
		Carbazole	1.7E-06	4.7E-06
		Chrysene	1.7E-06	4.7E-06
		Di-n-butyl phthalate	1.7E-06	4.7E-06
		Fluoranthene	7.8E-07	2.2E-06
		Ideno(1,2,3-c,d)pyrene	1.7E-06	4.7E-06
		Lead	1.0E-05	2.9E-05
		Phenanthrene	8.0E-07	2.2E-06
		Pyrene	8.0E-07	2.2E-06
		Selenium	1.3E-07	3.7E-07
	Ingestion of surface water while swimming in Thunderbay River	Carbon Tetrachloride	8.7E-10	2.4E-09
	Dermal contact with surface water from Thunderbay River	Carbon Tetrachloride	7.4E-09	2.1E-08
	Consumption of fish from Thunderbay River	Carbon Tetrachloride	1.7E-09	4.7E-09
	Ingestion of sediment from the backwater area of Thunderbay River	Anthracene	7.7E-08	2.2E-07
		Benzo(a)anthracene	7.7E-08	2.2E-07
		Benzo(a)pyrene	7.7E-08	2.2E-07
		Benzo(b)fluoranthene	7.7E-08	2.2E-07
		Benzo(ghi)perylene	7.7E-08	2.2E-07
		Benzo(k)fluoranthene	7.7E-08	2.2E-07
		Butyl benzyl phthalate	3.7E-08	1.0E-07
		Carbazole	7.7E-08	2.2E-07
		Chrysene	7.7E-08	2.2E-07
		Di-n-butyl phthalate	7.7E-08	2.2E-07
		Fluoranthene	3.7E-08	1.0E-07
		Ideno(1,2,3-c,d)pyrene	7.7E-08	2.2E-07
		Lead	1.2E-05	3.3E-05
		Phenanthrene	3.7E-08	1.0E-07
		Pyrene	3.7E-08	1.0E-07
		Selenium	1.5E-07	4.3E-07

Table 4-86 (continued)
Future Exposure Assessment - Site 6/7
MIANG, Alpena CRTC, Alpena, Michigan

Population	Exposure Pathway	Chemical	Chronic Daily Intake (CDI)(mg/kg-day) Carcinogenic Effects	Noncarcinogenic Effects
Recreational Child	Dermal contact with sediment from the backwater area of Lake Winyah	Anthracene	1.2E-06	5.8E-06
		Benzo(a)anthracene	1.2E-06	5.8E-06
		Benzo(a)pyrene	1.2E-06	5.8E-06
		Benzo(b)fluoranthene	1.2E-06	5.8E-06
		Benzo(ghi)perylene	1.2E-06	5.8E-06
		Benzo(k)fluoranthene	1.2E-06	5.8E-06
		Butyl benzyl phthalate	5.9E-07	2.8E-06
		Carbazole	1.2E-06	5.8E-06
		Chrysene	1.2E-06	5.8E-06
		Di-n-butyl phthalate	1.2E-06	5.8E-06
		Fluoranthene	5.9E-07	2.8E-06
		Ideno(1,2,3-c,d)pyrene	1.2E-06	5.8E-06
		Lead	7.6E-06	3.6E-05
		Phenanthrene	5.9E-07	2.8E-06
		Pyrene	5.9E-07	2.8E-06
		Selenium	9.9E-08	4.6E-07
	Ingestion of surface water while swimming in Thunderbay River	Carbon Tetrachloride	1.4E-09	6.3E-09
	Dermal contact with surface water from Thunderbay River	Carbon Tetrachloride	7.9E-09	3.7E-08
	Consumption of fish from Thunderbay River	Carbon Tetrachloride	2.1E-09	9.6E-09
	Ingestion of sediment from the backwater area of Thunderbay River	Anthracene	1.7E-07	2.0E-06
		Benzo(a)anthracene	1.7E-07	2.0E-06
		Benzo(a)pyrene	1.7E-07	2.0E-06
		Benzo(b)fluoranthene	1.7E-07	2.0E-06
		Benzo(ghi)perylene	1.7E-07	2.0E-06
		Benzo(k)fluoranthene	1.7E-07	2.0E-06
		Butyl benzyl phthalate	8.3E-08	9.6E-07
		Carbazole	1.7E-07	2.0E-06
		Chrysene	1.7E-07	2.0E-06
		Di-n-butyl phthalate	1.7E-07	2.0E-06
		Fluoranthene	8.3E-08	9.6E-07
		Ideno(1,2,3-c,d)pyrene	1.7E-07	2.0E-06
		Lead	2.7E-05	3.1E-04
		Phenanthrene	8.3E-08	9.6E-07
		Pyrene	8.3E-08	9.6E-07
		Selenium	3.5E-07	

4.12.4.1 Current Land-Use Conditions

No current land-use scenarios were quantitatively evaluated. Off-site risk characterization is discussed qualitatively in Section 4.12.6

4.12.4.2 Future Land-Use Conditions

Tables 4-87 and 4-88 present cancer risk estimates for the on-site child and adult, respectively. Detailed calculations are presented in Appendix U. Each table presents chemical-specific cancer risks, pathway cancer risks, and total exposure cancer risk for the on-site child and adult.

Future cancer risks exceeding the 1×10^{-6} reference level are calculated for the following pathways for the recreational child:

- Ingestion of sediments from the backwater area of Lake Winyah (exceeds the reference level but is the same order of magnitude)
- Dermal contact with sediments from the backwater area of Lake Winyah (exceeds the reference level by an order of magnitude).

The PAH compounds present in the sediments are the primary contributors to the elevated risk, with benzo (a) pyrene contributing 76% of the risk for both pathways.

The total future cancer risk for the recreational adult exceeds the 1×10^{-6} reference level. The dermal contact pathway exceeds the reference level by an order of magnitude. Benzo(a) pyrene contributes 76% of the risk for this scenario.

Tables 4-89 and 4-90 present chronic HI estimates for the on-site child and adult, respectively. Detailed calculations are presented in Appendix R. Subchronic HI estimates for the construction worker are also presented in Table 4-90. Each table presents chemical-specific HQs, pathway HIs, and total exposure HIs for the on-site child and adult.

No chemical-specific HQ or pathway HI is calculated above the reference level of 1. Total exposure HIs are below 1, indicating a low potential for adverse noncarcinogenic effects for both the on-site/recreational adult and recreational child.

4.12.5 Risk Assessment Uncertainties

This section presents a discussion of uncertainties involved in the process of quantifying risk for human receptors. Uncertainties involved in the exposure assessment, toxicity assessment, HI, and cancer risk estimation are discussed separately.

Table 4-87
Future Carcinogenic Risk Estimates for the Recreational Child - Site 6/7
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Dermal contact with sediment from the backwater area of Lake Winyah			
Anthracene	0E+00		
Benzo(a)anthracene	5E-06		
Benzo(a)pyrene	5E-05		
Benzo(b)fluoranthene	5E-06		
Benzo(ghi)perylene	0E+00		
Benzo(k)fluoranthene	5E-07		
Butyl benzyl phthalate	0E+00		
Carbazole	0E+00		
Chrysene	1E-08		
Di-n-butyl phthalate	0E+00		
Fluoranthene	0E+00		
Indeno(1,2,3-c,d)pyrene	5E-06		
Lead	0E+00		
Phenanthrene	0E+00		
Pyrene	0E+00		
Selenium	0E+00		
		7E-05	
Exposure Pathway: Ingestion of surface water while swimming in Thunderbay River			
Carbon Tetrachloride	2E-10		
		2E-10	
Exposure Pathway: Dermal contact with surface water from Thunderbay River			
Carbon Tetrachloride	1E-09		
		1E-09	
Exposure Pathway: Consumption of Fish fromThunderbay River			
Carbon Tetrachloride	3E-10		
		3E-10	

Table 4-87 (continued)
Future Carcinogenic Risk Estimates for the Recreational Child - Site 6/7
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Ingestion of sediments from the backwaters of Thunderbay River			
Anthracene	0E+00		
Benzo(a)anthracene	1E-07		
Benzo(a)pyrene	1E-06		
Benzo(b)fluoranthene	1E-07		
Benzo(ghi)perylene	0E+00		
Benzo(k)fluoranthene	1E-08		
Butyl benzyl phthalate	0E+00		
Carbazole	0E+00		
Chrysene	1E-09		
Di-n-butyl phthalate	0E+00		
Fluoranthene	0E+00		
Indeno(1,2,3-c,d)pyrene	1E-07		
Lead	0E+00		
Phenanthrene	0E+00		
Pyrene	0E+00		
Selenium	0E+00		
		2E-06	
Recreational Child - Total Future Cancer Risk			
			7E-05

Major Pathway Contributing to Risk	Major Chemical Contributing to Pathway Risk	Chemical Percent Contribution
Dermal Contact with Sediment	benzo(a) pyrene	76
Ingestion of Sediment	benzo(a) pyrene	76

Table 4-88
Future Carcinogenic Risk Estimates for the Recreational Adult - Site 6/7
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Dermal contact with sediment from the backwater area of Lake Winyah			
Anthracene	0E+00		
Benzo(a)anthracene	7E-06		
Benzo(a)pyrene	7E-05		
Benzo(b)fluoranthene	7E-06		
Benzo(ghi)perylene	0E+00		
Benzo(k)fluoranthene	7E-07		
Butyl benzyl phthalate	0E+00		
Carbazole	0E+00		
Chrysene	2E-08		
Di-n-butyl phthalate	0E+00		
Fluoranthene	0E+00		
Indeno(1,2,3-c,d)pyrene	7E-06		
Lead	0E+00		
Phenanthrene	0E+00		
Pyrene	0E+00		
Selenium	0E+00		
		9E-05	
Exposure Pathway: Ingestion of surface water while swimming in Thunderbay River			
Carbon Tetrachloride	1E-10		
		1E-10	
Exposure Pathway: Dermal contact with surface water from Thunderbay River			
Carbon Tetrachloride	1E-09		
		1E-09	
Exposure Pathway: Consumption of Fish fromThunderbay River			
Carbon Tetrachloride	2E-10		
		2E-10	

Table 4-88 (continued)
Future Carcinogenic Risk Estimates for the Recreational Adult - Site 6/7
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Ingestion of sediment from the backwater area of Thunderbay River.			
Anthracene	0E+00		
Benzo(a)anthracene	6E-08		
Benzo(a)pyrene	6E-07		
Benzo(b)fluoranthene	6E-08		
Benzo(ghi)perylene	0E+00		
Benzo(k)fluoranthene	6E-09		
Butyl benzyl phthalate	0E+00		
Carbazole	0E+00		
Chrysene	6E-10		
Di-n-butyl phthalate	0E+00		
Fluoranthene	0E+00		
Indeno(1,2,3-c,d)pyrene	6E-08		
Lead	0E+00		
Phenanthrene	0E+00		
Pyrene	0E+00		
Selenium	0E+00		
		7E-07	
Recreational Adult - Total Future Cancer Risk			
			9E-05

Major Pathway Contributing to Risk	Major Chemical Contributing to Pathway Risk	Chemical Percent Contribution
Dermal Contact with Sediment	benzo(a) pyrene	76
		76

Table 4-89
Estimate of Future Noncarcinogenic Effects for the Recreational Child - Site 6/7
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal contact with sediment from the backwater area of Lake Winyah			
Anthracene	1E-04		
Benzo(a)anthracene	1E-03		
Benzo(a)pyrene	1E-03		
Benzo(b)fluoranthene	1E-03		
Benzo(ghi)perylene	1E-03		
Benzo(k)fluoranthene	1E-03		
Butyl benzyl phthalate	6E-04		
Carbazole	0E+00		
Chrysene	3E-04		
Di-n-butyl phthalate	7E-05		
Fluoranthene	4E-04		
Indeno(1,2,3-c,d)pyrene	1E-03		
Lead	0E+00		
Phenanthrene	6E-04		
Pyrene	6E-04		
Selenium	9E-05		
		1E-02	
Exposure Pathway: Ingestion of surface water while swimming in Thunderbay River			
Carbon Tetrachloride	9E-06		
		9E-06	
Exposure Pathway: Dermal contact with surface water from Thunderbay River			
Carbon Tetrachloride	6E-05		
		6E-05	
Exposure Pathway: Consumption of Fish fromThunderbay River			
Carbon Tetrachloride	1E-05		
		1E-05	

Table 4-89 (continued)
Estimate of Future Noncarcinogenic Effects for the Recreational Child - Site 6/7
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of sediment from the backwater area of Thunderbay River			
Anthracene	7E-06		
Benzo(a)anthracene	7E-05		
Benzo(a)pyrene	7E-05		
Benzo(b)fluoranthene	7E-05		
Benzo(ghi)perylene	7E-05		
Benzo(k)fluoranthene	7E-05		
Butyl benzyl phthalate	0E+00		
Carbazole	0E+00		
Chrysene	0E+00		
Di-n-butyl phthalate	2E-05		
Fluoranthene	2E-05		
Indeno(1,2,3-c,d)pyrene	7E-05		
Lead	0E+00		
Phenanthrene	3E-05		
Pyrene	3E-05		
Selenium	8E-04		
		1E-03	
Recreational Child - Total Future Hazard Index			
			1E-02

Table 4-90
Estimate of Future Noncarcinogenic Effects for the Recreational Adult - Site 6/7
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Dermal contact with sediment from the backwater area of Lake Winyah			
Anthracene	9E-05		
Benzo(a)anthracene	9E-04		
Benzo(a)pyrene	9E-04		
Benzo(b)fluoranthene	9E-04		
Benzo(ghi)perylene	9E-04		
Benzo(k)fluoranthene	9E-04		
Butyl benzyl phthalate	4E-04		
Carbazole	0E+00		
Chrysene	2E-04		
Di-n-butyl phthalate	6E-05		
Fluoranthene	3E-04		
Indeno(1,2,3-c,d)pyrene	9E-04		
Lead	0E+00		
Phenanthrene	4E-04		
Pyrene	4E-04		
Selenium	7E-05		
		8E-03	
Exposure Pathway: Ingestion of surface water while swimming in Thunderbay River			
Carbon Tetrachloride	3E-06		
		3E-06	
Exposure Pathway: Dermal contact with surface water from Thunderbay River			
Carbon Tetrachloride	3E-05		
		3E-05	
Exposure Pathway: Consumption of Fish fromThunderbay River			
Carbon Tetrachloride	7E-06		
		7E-06	

Table 4-90(continued)
Estimate of Future Noncarcinogenic Effects for the Recreational Adult - Site 6/7
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of sediments from the backwater area of Thunderbay River			
Anthracene	7E-07		
Benzo(a)anthracene	7E-06		
Benzo(a)pyrene	7E-06		
Benzo(b)fluoranthene	7E-06		
Benzo(ghi)perylene	7E-06		
Benzo(k)fluoranthene	7E-06		
Butyl benzyl phthalate	0E+00		
Carbazole	0E+00		
Chrysene	0E+00		
Di-n-butyl phthalate	2E-06		
Fluoranthene	3E-06		
Indeno(1,2,3-c,d)pyrene	7E-06		
Lead	0E+00		
Phenanthrene	3E-06		
Pyrene	3E-06		
Selenium	9E-05		
		1E-04	
Recreational Adult - Total Future Hazard Index			
			8E-03

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4.12.5.1 Exposure Assessment Uncertainties

Uncertainty in the exposure assessment is a function of the completeness of site data, assumptions that simplify and approximate actual current or future site conditions, and professional judgement used in developing and evaluating various parameters. Assumptions and inferences must be made to develop exposure scenarios. These assumptions and inferences introduce uncertainties into the exposure assessment.

95 percent UCLs for sediment were calculated based on three samples collected from the toe of the landfill. It was noted that the sediment contained asphalt-like particles. It is likely that the concentration of PAHs detected in these sediments is overestimated and would be significantly lower further away from the toe of the landfill.

The exposure scenarios presented are conservative, and overestimate rather than underestimate exposure. The approach is conservative and is designed to compensate for uncertainties inherent in the exposure assessment. The use of very conservative health-protective exposure factors in the exposure assessment process results in final intake values that are extremely conservative. RME chronic intake values may be overestimated by one to two orders of magnitude.

In quantifying exposure levels, the chemicals are assumed to be uniformly distributed over the defined area, thus resulting in a uniform exposure level. Chemical analytical data were obtained from a directed sampling program, i.e., sampling locations were generally selected on the basis of where contaminants were expected to be present. Sampling zones found to be free of contamination received less investigation. This sampling scheme tends to greatly overestimate the overall chemical concentrations at a site.

One of the assumptions used in the exposure assessment is that the current chemical concentrations in groundwater and future modeled chemical concentrations are assumed to remain constant over exposure pathway duration and that the transport mechanisms are assumed to have reached equilibrium. This means that the levels will not decrease due to the exhaustion of the contaminant sources over the assumed exposure periods. The result of this assumption is a probable overestimation of GSI exposure point concentrations because contaminant sources will not likely remain constant over time.

Finally, the assumption is made that human exposure remains constant over the lifetime of an individual. In actuality, lifestyle changes due to age and actual residence time will alter the projected exposure durations. Movement of individuals in and out of the potentially exposed community also affects exposure duration.

4.12.5.2 Toxicity Assessment

RfDs developed by the EPA are generally considered to have uncertainty spanning an order of magnitude or more. Consequently, total exposure HIs for the resident child and adult may be estimated high or low by an order of magnitude or more.

Low confidence by EPA in an RfD value, such as low confidence in the Cr(VI) oral RfD, indicates high uncertainty in the accuracy of the toxicity value. High uncertainty indicates

that the value may change in the future if additional toxicity data where to become available. Conversely, high confidence by the EPA in an RfD indicates low uncertainty in the accuracy of the toxicity value.

SFs developed by the EPA are generally conservative and represent the upper bound limit of the probability of a cancer response. Thus, the actual cancer risk due to exposure to the chemicals of concern is likely to be lower than the estimated risk.

A second area of uncertainty is those chemicals which were not included in the quantitative assessment because of lack of carcinogenic or noncarcinogenic toxicity values. Chemicals lacking RfD values include butyl benzyl phthalate, carbazole, chrysene, and lead, and those lacking SFs include di-n-butyl phthalate, fluoranthene, lead, phenanthrene, pyrene anthracene, butyl benzyl phthalate, carbazole, and selenium. The total risk without considering these chemicals is underestimated.

4.12.6 Conclusions

No current pathways are considered complete for Site 6/7. A summary of future carcinogenic and noncarcinogenic risks was presented previously in Tables 4-91 through 4-94.

Per MDNR guidance, a cancer risk exceeding 1×10^{-6} is an unacceptable human health risk (EPA, 1989). The total future cancer risks for the on-site adult and child exceed the 1×10^{-6} reference level. Dermal contact with sediment exceeds the reference level by an order of magnitude for both the adult and child. Benzo (a) pyrene contributes 76% of the risk for both scenarios.

For noncarcinogenic effects, EPA guidance considers a HI greater than 1 to indicate potential for adverse noncarcinogenic health effects (EPA, 1989b). It has been demonstrated that the future HIs for the adult and child are below this reference level, indicating a low potential for adverse noncarcinogenic health effects.

Uncertainties in the risk assessment were evaluated in Section 4.12.5. The largest uncertainty for the Site 6/7 health assessment is the concentration of chemicals of concern in the backwater area of Lake Winyah. Only three samples were collected; all three were collected at the edge of the landfill. Asphalt particles were noted in the sediment samples. The concentrations are likely biased high and may be significantly lower away from the toe of the landfill.

No data are available regarding the deeper limestone aquifer. The potential for groundwater contaminants to migrate from the shallow aquifer to the deeper aquifer and contaminate on-site or off-site drinking wells was qualitatively assessed. No continuous clay layer, sufficiently thick to be considered an aquitard, was found at Site 5, consequently, the potential exists for contaminants to migrate vertically into the limestone aquifer if a vertical hydraulic gradient exists between the two aquifers. Carbon tetrachloride detected in the groundwater is a class B2 carcinogen and could pose a health threat if exposure occurs.

4.13 SITE 8 - FORMER SITE OF HANGAR 9

A baseline risk assessment was conducted for Site 8, Former Site of Hangar 9, to estimate the health risk for human receptors.

Section 4.13.1 identifies the chemicals of potential concern. Section 4.13.2 presents an exposure assessment for human receptors. The toxicity assessment for chemicals of potential concern was previously presented in Section 4.4. The risk characterization for carcinogenic and noncarcinogenic effects is presented in Section 4.13.4. Uncertainties in the human health assessment are discussed in Section 4.13.5. Section 4.13.6 presents a summary of total carcinogenic risk and the total exposure HIs for on-site adults and children.

4.13.1 Identification of Chemicals of Potential Concern

Chemicals of potential concern at Site 8 were selected for soils and groundwater through the process outlined in Section 4.2. The results of the selection process are presented in Section 4.13.1.1 and 4.13.1.2.

4.13.1.1 Selection of Chemicals of Potential Concern within the Soil

Tables 3-19 and 3-20 present a summary of the validated surface (0 to 0.6 m [0 to 2 ft]) and subsurface soil data collected during the RI. The complete data set is included in Appendix L. Additionally, soil data from the SI is included in Appendix N and O but was not used to estimate risk. Tables 4-91 and 4-92 presents a summary of the range of detected concentrations, the number of detections, and the MDNR criteria used in the evaluation.

The following chemicals were detected in the surface soil above the MDNR Type B criteria and have been identified as chemicals of potential concern:

- Antimony
- Lead.

4.13.1.2 Selection of Chemicals of Potential Concern within the Shallow Aquifer

Table 3-21 presents a summary of the groundwater data collected at Site 8 during the RI. The complete data set is included in Appendix L. Data from the three rounds of groundwater sampling prior to the RI are presented in Appendix N and O but were not used to estimate risk. Table 4-93 presents a summary of the range of detected concentrations, the number of detections, and the MDNR criteria used in the evaluation.

Tetrachloroethylene was detected at levels above the Act 307 Type B cleanup criteria and has been selected as a chemical of potential concern.

Table 4-91 Data Summary Table: Surface Soil, Site 8-Former Site of Hangar 9 MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/kg)	Act 307* Cleanup Criteria (µg/kg)
Aromatic Volatiles (ppb)			
1,2-Dichlorobenzene	1 / 3	0.041 / 0.041	12000
Benzene	1 / 3	0.06 / 0.06	24
Methyl-t-Butyl Ether	1 / 3	2.4 / 2.4	4600
Halogenated Volatiles (ppb)			
1,1,1-Trichloroethane	1 / 3	0.059 / 0.059	4000
Methylene chloride	1 / 3	8.4 / 8.4	92
Semivolatiles (ppb)			
Benzo(b)fluoranthene	1 / 3	48 / 48	180{G}
Chrysene	1 / 3	74 / 74	180{G}
bis(2-Ethylhexyl)phthalate	1 / 3	52 / 52	92000{G}
Metals (ppb)			
Aluminum	1 / 1	3350000 / 3350000	6900000
Antimony	1 / 3	5100 / 5100	4614
Arsenic	1 / 3	630 / 630	5800
Barium	1 / 1	14900 / 14900	75000
Calcium	1 / 1	1230000 / 1230000	
Chromium	3 / 3	2900 / 7000	18000
Cobalt	1 / 1	1300 / 1300	
Copper	2 / 3	1900 / 3900	32000
Iron	1 / 1	3540000 / 3540000	12000000
Lead	2 / 3	2200 / 42600	21000
Manganese	1 / 1	193000 / 193000	440000
Magnesium	1 / 1	444000 / 444000	
Potassium	1 / 1	268000 / 268000	
Selenium	1 / 3	340 / 340	410
Sodium	1 / 1	31200 / 31200	3000000
Vanadium	1 / 1	8200 / 8200	1200{C}
TPH (ppb)			
Total Petroleum Hydrocarbons	3 / 3	13800 / 11000000	NA

* Refer to Table 4-1 for explanation of Act 307 footnotes.
NA - Not Available

wp/t4-91.775-06/15/95

Table 4-92 Data Summary Table: Subsurface Soil, Site 8-Former Site of Hangar 9 MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (μg/kg)	Act 307* Cleanup Criteria (μg/kg)
Aromatic Volatiles (ppb)			
1,2-Dichlorobenzene	1 / 11	0.056 / 0.056	12000
Chlorobenzene	2 / 11	0.12 / 0.14	2600
Ethylbenzene	3 / 11	0.025 / 0.1	1500
Methyl-t-Butyl Ether	1 / 11	0.61 / 0.61	4600
Toluene	2 / 11	0.063 / 0.28	16000
Halogenated Volatiles (ppb)			
Bromodichloromethane	/ 11	0.27 / 0.27	11
Semivolatiles (ppb)			
Di-n-butyl phthalate	1 / 11	36 / 36	17000
Metals (ppb)			
Aluminum	6 / 6	982000 / 4120000	6900000
Arsenic	6 / 11	440 / 1200	5800
Barium	6 / 6	2600 / 17000	75000
Calcium	6 / 6	531000 / 39400000	
Chromium	11 / 11	1700 / 6500	18000
Chromium, Hexavalent	1 / 11	12 / 12	
Cobalt	5 / 6	1000 / 1400	
Copper	3 / 11	1800 / 2800	32000
Iron	6 / 6	2130000 / 4490000	12000000
Lead	6 / 11	790 / 1800	21000
Manganese	6 / 6	42400 / 133000	440000
Magnesium	6 / 6	502000 / 5520000	
Nickel	2 / 11	3900 / 4300	20000
Potassium	3 / 6	263000 / 366000	
Sodium	6 / 6	28100 / 64900	3000000
Vanadium	6 / 6	4100 / 10300	1200(C)
TPH (ppb)			
Total Petroleum Hydrocarbons	9 / 11	11200 / 147000	NA

* Refer to Table 4-1 for explanation of Act 307 footnotes.

NA - Not Available

wp/t4-92.775-06/15/95

Table 4-93 Data Summary Table: Groundwater, Site 8-Former Site of Hangar 9 MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/l)	Background Concentrations (µg/l)	Act 307* Cleanup Criteria (µg/l)
Aromatic Volatiles (µg/l)				
1,2-Dichlorobenzene	1 / 6	2.2 / 2.2	ND	600
Ethylbenzene	2 / 6	0.11 / 0.12	ND	74(R)
Toluene	2 / 6	0.2 / 0.24	ND	790R)
Halogenated Volatiles (µg/l)				
Tetrachloroethylene	1 / 6	1.2 / 1.2	ND	0.7
Low Con. Semivolatiles (µg/l)				
Diethyl phthalate	3 / 6	0.6 / 5	ND	5200
Dimethyl phthalate	1 / 6	1 / 1	ND	70000
Metals (µg/l)[1)]				
Arsenic	1 / 6	13.3 / 13.3	/	
Chromium	1 / 6	46.3 / 46.3	/	
Copper	1 / 6	55.6 / 55.6	/	
Lead	1 / 6	44 / 44	/	
Nickel	1 / 6	61.3 / 61.3	/	
Selenium, Dissolved	1 / 6	6.2 / 6.2	/	35(C)
Zinc	1 / 6	137 / 137	/	

* Refer to Table 4-1 for explanation of Act 307 footnotes.
[1)]Criteria is presented for dissolved metals only.

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4.13.2 Exposure Assessment

The purpose of the exposure assessment is to estimate the type and magnitude of human receptor exposure to chemicals of potential concern resulting from Site 8 activities. The following exposure assessment components are evaluated in this section:

- Characterization of the exposure setting (Section 4.13.2.1)
- Identification of exposure pathways/receptors (Section 4.13.2.2)
- Estimation of chemical concentrations at receptors (Section 4.13.2.3)
- Estimation of on-site child and adult intake values (Section 4.13.2.4).

4.13.2.1 Characterization of the Exposure Setting

Site 8 is the former site of Hangar 9. The concrete foundation is all that remains of the hangar. Areas adjacent to Site 8 consist of control tower, maintenance shops, and taxiways. The nearest surface water body is the sinkhole, which is located approximately 686 m (2,250 ft) northwest of Site 8 (Figure 1-10). No recreational activities occur in the sinkhole by facility personnel or visitors to the facility.

The subsurface material underlying the site consists mainly of medium- to coarse-grained quartz sands. The Traverse Group Limestone is present at approximately 20 m (65 ft). No continuous clay layer, which could act as an aquitard, was present between the sand unit and the limestone.

The direction of shallow groundwater flow beneath Site 8 is north-northwest towards the sinkhole. Depth to the water table varies from 3 to 5.5 m (10 to 18 ft) bgs. The limestone bedrock lies beneath the shallow aquifer. The shallow aquifer at Site 8 likely contains sufficient water to support drinking wells. The direction of groundwater flow in the limestone aquifer is unknown. Off-site residential wells screened in the limestone aquifer are present to the north, south, and east of the Alpena CRTC.

The drinking water supply for Alpena CRTC consists of on-site production wells. These wells are located west of Site 8. PW1, the main production well is screened in the limestone aquifer. PW2 is screened in the shallow and limestone aquifer and consequently, provides a conduit for migration of contaminants from the shallow aquifer into the limestone aquifer. Shallow groundwater flow at Site 8 is north towards the sinkhole, consequently, little potential exists for contaminants in the shallow groundwater to migrate to PW2.

4.13.2.2 Identification of Exposure Pathways/Receptors

The ANG holds the lease on the land until 2039; therefore, the current land-use has been evaluated for future exposure. No full-time employees are located at the site. Full-time employees are located in the maintenance shops adjacent to the site. Training personnel use the area during training activities which take place during the months of April through

September for two-week sessions. Families of training personnel may visit on the weekends and use the recreational facilities.

An alternate future land-use which will be considered is recreational use of the area. Residential land-use is considered highly improbable due to the location of the site in a rural area with low growth.

The following potential current exposure pathways and receptors were identified:

- Dermal contact of soils by facility personnel
- Incidental ingestion of soil by facility personnel
- Inhalation of dust from soils by facility personnel
- Ingestion of contaminated groundwater by off-site residents
- Ingestion of contaminated groundwater by facility personnel.

The following future exposure pathways and receptors were also identified:

- Future dermal contact of soils by construction workers, adults, or children
- Future incidental ingestion of soils by construction workers, adults, or children
- Future inhalation of dust from soils by construction workers, adults, or children
- Future ingestion of contaminated fish caught in the sinkhole by adults and children
- Future incidental ingestion of contaminated surface water by adults and children playing in the sinkhole
- Future dermal absorption of contaminated surface water by adults and children playing in the sinkhole
- Future inhalation of vapor phase chemicals during shallow groundwater domestic use by on-site personnel or visitors
- Future dermal absorption of contaminated shallow groundwater use by on-site personnel or visitors
- Future ingestion of contaminated groundwater by off-site residents
- Future ingestion of contaminated groundwater from future shallow aquifer wells by on-site personnel or visitors.

Receptors include recreational adults and children and off-site residents.

The current and future potential pathways involving the current on-site drinking wells are addressed in Section 4.7. The future potential pathways involving the sinkhole are addressed in Section 4.10.

The site is grass covered, consequently, the following current and future pathways are considered incomplete and are not considered further:

- Current inhalation of dust from soils by facility personnel
- Future inhalation of dust from soils by recreational adults and children.

Based on the elimination of all incomplete pathways, Table 4-94 presents the current and future exposure pathways which are considered complete and are not addressed elsewhere.

4.13.2.3 Estimation of Chemical Concentrations at Receptors

The 95 percent UCL of the arithmetic mean, as outlined in Section 4.2, was calculated as the chemical exposure concentration for the following receptor exposure points. Table 4-95 presents the reasonable maximum exposure concentrations.

- Current and future dermal contact with soil
- Current and future ingestion of soil
- Future inhalation of soil
- Future dermal contact with shallow aquifer
- Future inhalation of vapor phase chemicals from shallow groundwater
- Future ingestion of shallow groundwater

No data currently exist regarding off-site residential groundwater. These pathways are therefore addressed qualitatively.

Future concentrations of chemicals of potential concern in groundwater were predicted using a two-dimensional MOC solute transport model. The model estimates the peak concentration of chemicals of concern in the groundwater which will discharge to the sinkhole over time. Details of the model are included in Appendix V.

4.13.2.4 Estimation of On-site Child and Adult Intake Values

On-site child and adult CDI for carcinogenic effects and subchronic noncarcinogenic effects were estimated for exposure pathways identified in Table 4-95. Tables 4-96 through 4-101 present the formulas and assumptions used to model current and future RME intake values for each identified exposure pathway. Standard default exposure factors were used to estimate intake where applicable; acceptable exposure factor references are listed for those standard

Table 4-94 Current and Future Exposure Pathways – Site 8
MIANG, Alpena, CRTC, Michigan

Receptor Population	Exposure Point	Exposure Pathway
Current Land-use		
Adult	on-site	Dermal contact with contaminated soil
Adult	on-site	Ingestion of contaminated soil
Adult and child	off-site	Ingestion of bedrock aquifer groundwater
Future Land-use		
Recreational Adult and Child and Excavation Worker	on-site	Future dermal contact with contaminated soil
Recreational Adult and Child and Excavation Worker	on-site	Future ingestion of contaminated soil
Excavation Worker	on-site	Future inhalation of contaminated soil
Adult and child	on-site	Future ingestion of shallow groundwater
Adult and child	on-site	Future inhalation of vapor phase chemicals from shallow groundwater use
Adult and child	on-site	Future dermal absorption of shallow groundwater
Adult and child	off-site	Future ingestion of bedrock aquifer groundwater

default exposure factors. Reasonable assumptions were made to quantify site-specific exposure factors. Site-specific assumptions were necessary to estimate exposure frequencies for children. Children of visiting or full-time employees may use the on-site facilities during the weekends. It was assumed that children would be present on-site 6 months per year for 8 days per month for a total of 48 days per year. It was further assumed that these children would be present through the childhood years (0-15 years) for an exposure duration of 15 years. These assumptions were also assumed to be applicable for the recreational land-use scenario. This scenario assumes that the adult works at the recreational area for 250 days/year and participates in recreational activity at the area for an additional 48 days/year. This provides a worst case scenario for exposure to groundwater.

Using the exposure intake models presented in Tables 4-96 through 4-101, current and future chemical intake values were estimated for the potential receptors previously identified. Tables 4-102 and 4-103 present a summary of the exposure assessment for current and future land-use at Site 8.

4.13.3 Toxicity Assessments

Toxicity profiles for chemicals of potential concern were presented previously in section 4.4.1 Toxicity Profiles. Section 4.4.2, Toxicity Values, presents the toxicity values for chemicals of potential concern.

Table 4-95
Reasonable Maximum Exposure Concentrations- Site 8
MIANG, Alpena CRTC, Alpena, Michigan

Matrix	Compound	Units	Arithmetic Mean	N	Maximum Value	Minimum Value	95% UCL
GROUNDWATER	Tetrachloroethylene	ug/l	0.36	5	1.2	0.15	0.80772
SOIL	Antimony	mg/kg	3.28333	3	5.1	2.35	5.936
SOIL	Lead	mg/kg	22.4	2	42.6	2.2	149.94278

If 95% UCL is greater than the maximum value, then the maximum value is the reasonable maximum exposure concentration.

Table 4-96 Model for Estimating Current and Future Chemical Absorbed Dose by Adults and Children Through Dermal Contact with Soils - Site 8 MIANG, Alpena CRTC, Alpena, Michigan

$$Absorbed\ Dose\ (mg/kg\text{-}day) = \frac{CS \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

where:

CS	=	Chemical Concentration in Soil (mg/kg)
CF	=	Conversion Factor (10^{-6} kg/mg)
SA	=	Skin Surface Area Available for Contact (cm^2/event)
AF	=	Soil to Skin Adherence Factor (mg/cm^2)
ABS	=	Absorption Factor (unitless)
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Facility Employee	Recreational Adult	Recreational Child	Construction Worker
Surface area (cm^2/day)	3,120	3,120	1,490	3,120[1]
Soil to Skin Adherence Factor (mg/cm^2)	2.77	2.77	2.77	2.77
Absorption Factor	.01 .25	.01 .25	.01 .25	0.01 metals[2] 0.25 organics
Exposure Frequency (days/yr)	250	298[4]	48	250[3]
Exposure Duration (years)	25	25	15	.08[2]
Body Weight (kg)	70	70	27	70[3]
Averaging Time (year), (noncarcinogenic)	25	25	15	.08

Notes:
1) U.S. Environmental Protection Agency, 1989b - Total of arms and hands
2) estimate
3) U.S. Environmental Protection Agency, 1991.
4) Assumes the adult works on-site 250 days/year and uses the recreational facilities an additional 48.

Table 4-97 Model for Estimating Current Future Chemical Intake by Adults through Soil Ingestion - Site 8 MIANG, Alpena CRTC, Alpena, Michigan

$$Intake\ (mg/kg\text{-}day) = \frac{CS \times IR \times CF \times FI \times EF \times ED}{BW \times AT}$$

where:

CS	=	Chemical Concentration in Soil (mg/kg)
IR	=	Ingestion Rate (mg/day)
CF	=	Conversion Factor (10^{-6} kg/mg)
FI	=	Fraction Ingested from Contaminated Source (unitless)
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Facility Employee	Recreational Adult	Recreational Child	Construction Worker[1]
Ingestion Rate (IR) (mg/day)	100	100	200	480
Fraction Ingested	1	1	1	1
Exposure Frequency (days/yr)	250	298[2]	48[2]	250
Age Group (years)	16-65	16-65	1-6	16-65
Exposure Duration (years)	25	25	6	.08
Body Weight (kg)	70	70	15	70
Averaging Time (years), (noncarcinogenic)	25	25	6	.08

Notes:

1) All values from U.S. Environmental Protection Agency, 1991.

2) Site-specific estimate - see 4.13.2.4

Table 4-98 Model for Estimating Future Intake by On-site Adults through Inhalation of Fugitive Dust from Soil - Site 8
MIANG, Alpena CRTC, Alpena, Michigan

$$Intake\ (mg/Kg\text{-}day) = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$$

where:

CA	=	Contaminant Concentration in Air (mg/m^3)
IR	=	Inhalation Rate (m^3/hour)
ET	=	Exposure Time (hours/day)
EF	=	Exposure Frequency (days/year)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).
CA	=	$D_L \times C_S \times C_F$
D_L	=	Dust Loading Factor (g/m^3)
C_S	=	Chemical Concentration in Soil (g/g)
C_F	=	Conversion Factor (10^{-3} mg/g)

Default dust loading factors will be used in the absence of site-specific data (DOE, 1983):

- Construction Work - 600 g/m^3
- Construction Traffic - 400 g/m^3

Assumptions:	Adult[1]
Inhalation Rate (m^3/hr)	20
Exposure Time (hours/day)	8
Exposure Frequency (days/year)	250
Exposure Duration (years)	0.08
Body Weight (kg)	70
Averaging Time (years)	
Carcinogens	70
Noncarcinogens	0.08

Notes:
1) U.S. Environmental Protection Agency, 1991.

Table 4-99 Model for Estimating Future Chemical Absorbed Dose by Adults and Children through Dermal Contact with Chemicals in Groundwater - Site 8 MIANG, Alpena CRTC, Alpena, Michigan

$$\textit{Absorbed Dose (mg/kg-day)} = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

where:

CW	=	Chemical Concentration in Water (mg/ℓ).
SA	=	Skin Surface Area Available for Contact (cm^2).
PC	=	Chemical-specific Dermal Permeability Constant (cm/hr) default 8.4 x 10
ET	=	Exposure Time (hours/day).
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
CF	=	Volumetric Conversion Factor for Water (1 liter/1000 cm^3)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	On-Site/Recreational Adult	Child
CW[5]		
Skin Surface Area (cm^2)	19,400[1]	13,300[1]
Dermal Permeability Constant (cm/hr)	8.4×10^{-4} [2]	8.4×10^{-4} [2]
Exposure Time (hours/day)	.25[4]	.25[4]
Exposure Frequency (days/yr)	48[3]	48[3]
Exposure Duration (years)	25[3]	15[3]
Body Weight (kg)	70	27[2]
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) U.S. Environmental Protection Agency, 1989b – Child is average for ages 0-15.
2) U.S. Environmental Protection Agency, 1989a.
3) Site specific assumption – See Section 4.8.2.4
4) 15 minute exposure.
5) Chemical-specific permeability constants were used where available: PCE 4×10^{-1} (Tab 5-3 EPA, 92)

Table 4-100 Model for Estimating Future Chemical Intake by On-site Adults and Children through Inhalation of Vapor Phase Chemicals in the Groundwater - Site 8 MIANG, Alpena CRTC, Alpena, Michigan

$$Intake\ (mg/Kg\text{-}day) = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$$

where:

- CA = Contaminant Concentration in Air (mg/m^3)
- IR = Inhalation Rate (m^3/hour)
- ET = Exposure Time (hours/day)
- EF = Exposure Frequency (days/year)
- ED = Exposure Duration (years)
- BW = Body Weight (kg)
- AT = Averaging Time (period over which exposure is averaged, in days).

Assumptions:

$$CA\ (air\ contaminant\ concentration,\ mg/m^3) = \frac{CA_{max}/2)t_1 + CA_{max}t_2}{V_a}\ (1),$$

$$Where:\ CA_{max} = \frac{C_w f F_w t_1}{V_a}\ (1)$$

Where:

- C_w = The arithmetic mean or the 95% upper confidence limit (UCL) of the arithmetic mean of the contaminant concentration in shower water (mg/ℓ). Contaminant concentrations in groundwater are used as shower water concentrations.
- f = The fraction volatilized (unitless) is 0.7 (i.e., the mean of the range of 0.5 to 0.9) (Andelman, 1990).
- F_w = The water flow rate (ℓ/hr) is 750 ℓ/hr (i.e., the mean of the range 500 to 1,000 ℓ/hr) (Wang, 1992).
- t_1 = The duration period for showering (hr) is 0.25 hr (SEAM, 1988).
- t_2 = The duration period for the time after showering is 0.35 hr (i.e., the mean of the range of 0.2 to 0.5 hr) (Wang, 1992).
- V_a = The bathroom volume (m^3) is 11 m^3 (i.e., the mean of the range of 6 to 16 m^3) (Wang, 1992).

[1] Reference: Wang, 1992.

	On-Site/Recreational Adult	Child
Inhalation Rate (m^3/hr)	0.6[1]	0.6[1]
Exposure Time (minutes	7[1]	7[1]
Exposure Frequency (days/year)	298[3]	48[3]
Exposure Duration (years)	25[2]	15[2]
Body Weight (kg)	70[2]	27
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) U.S. Environmental Protection Agency, 1989b.
2) U.S. Environmental Protection Agency, 1991.
3) Site specific assumption – see Section 4.13.2.4.

Table 4-101 Model for Estimating Future Chemical Intake by On-site Adults and Children through Drinking Water Ingestion – Site 8 MIANG, Alpena CRTC, Alpena, Michigan

$$CDI\ (mg/Kg\text{-}day) = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

where:

CDI	=	Chronic Daily Intake (mg/kg-day), representing the reasonable maximum exposure (RME).
CW	=	Chemical Concentration in Groundwater (mg/ℓ).
IR	=	Drinking Water Ingestion Rate (ℓ/day).
EF	=	Exposure Frequency (days/year).
ED	=	Exposure Duration (years).
BW	=	Body Weight (kg).
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:

	On-Site/Recreational[1]	Child
Ingestion Rate (IR) (ℓ/day)	2	2[2]
Exposure Frequency (EF) (days/yr)	298	48[3]
Exposure Duration (ED) (years)	25	15[3]
Body Weight (kg)	70	27[2]
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) All values from U.S. Environmental Protection Agency, 1991.
2) U.S. Environmental Protection Agency, 1989.
3) Site specific assumption – see Section 4.13.24.

Table 4-102
Exposure Assessment - Current Land Use - Site 8
MIANG, Alpena CRTC, Alpena, Michigan

Population	Exposure Pathway	Chemical	Chronic Daily Intakes (CDI)(mg/kg-day) Carcinogenic Effects	Noncarcinogenic Effects
On-Site Employee	Ingestion of soils	Antimony	1.8E-06	5.0E-06
		Lead	1.5E-05	4.2E-05
	Dermal contact with soils	Antimony	1.5E-06	4.3E-06
		Lead	1.3E-05	3.6E-05

Table 4-103
Exposure Assessment - Future Land Use - Site 8
MIANG, Alpena CRTC, Alpena, Michigan

Population	Exposure Pathway	Chemical	Chronic Daily Intakes (CDI)(mg/kg-da Carcinogenic Effects	Noncarcinogenic Effects	Subchronic Daily Intakes (SDI) (mg/kg-da Noncarcinogenic Effects
Excavation Workers	Ingestion of soils	Antimony	2.7E-08		2.4E-05
		Lead	2.3E-07		2.0E-04
	Dermal contact with soils	Antimony	4.9E-09		4.3E-06
		Lead	4.1E-08		3.6E-05
	Inhalation of soils	Antimony	9.1E-08		8E-05
		Lead	7.6E-07		6.7E-04
On-Site/Recreational Adult	Ingestion of groundwater	Tetrachloroethylene	6.7E-06	1.9E-05	
	Dermal contact with groundwater	Tetrachloroethylene	6.5E-06	1.8E-05	
	Inhalation of vapor-phase chemical released from groundwater	Tetrachloroethylene	2.3E-06	6.4E-06	
	Ingestion of soils	Antimony	2.1E-06	5.9E-06	
		Lead	1.8E-05	5E-06	
	Dermal contact with soils	Antimony	1.8E-06	5.1E-06	
		Lead	1.5E-05	4.3E-05	
Recreational Child	Ingestion of groundwater	Tetrachloroethylene	1.7E-06	7.9E-06	
	Dermal contact with groundwater	Tetrachloroethylene	1.1E-06	5.2E-06	
	Inhalation of vapor-phase chemical released from groundwater	Tetrachloroethylene	5.7E-07	2.7E-06	
	Ingestion of soils	Antimony	7.7E-07	8.9E-06	
		Lead	6.4E-06	7.5E-05	
	Dermal contact with soils	Antimony	2.2E-07	1E-06	
		Lead	1.8E-06	8.6E-06	

4.13.4 Risk Characterization

The potential risks associated with the chemicals of concern were evaluated as outlined in Section 4.5. Section 4.13.4.1 presents the risk characterization for current land-use and Section 4.13.4.2 presents the future land-use risk characterization.

4.13.4.1 <u>Current Land-Use Conditions</u>

No SFs are currently available for antimony and lead; therefore, no carcinogenic risks were computed for the current pathways.

Table 4-104 presents chronic HI estimates for the on-site adult. Detailed calculations are presented in Appendix V. The table presents chemical-specific HQs, pathway HIs, and total exposure HIs for the on-site adult.

No pathway HIs were above the reference level of 1. Total HI for the current on-site adult was also below 1.

4.13.4.2 <u>Future Land-Use Conditions</u>

Tables 4-105 and 4-106 present cancer risk estimates for the recreational child and on-site/recreational adult, respectively. Detailed calculations are presented in Appendix V. Each table presents chemical-specific cancer risks, pathway cancer risks, and total exposure cancer risk for the on-site child and adult. No SFs were available for antimony and lead, consequently, no cancer estimate was calculated for the excavation worker.

No future pathway carcinogenic risks exceeding the reference level of 1×10^{-6} were computed for the recreational child. Total carcinogenic risk for the recreational child are below 1×10^{-6}.

No future pathway carcinogenic risk exceeding 1×10^{-6} is determined for the future ingestion of groundwater for the on-site/recreational adult. Total carcinogenic risk for the adult is 1×10^{-6} level.

Tables 4-107 and 4-108 present chronic HI estimates for the recreational child and on-site/recreational adult, respectively. Detailed calculations are presented in Appendix V. Subchronic HI estimates for the construction worker are presented in Table 4-109. Each table presents chemical-specific HQs, pathway HIs, and total exposure HIs for the on-site child and adult.

Future pathway HIs for the recreational child are below the reference level of 1. Total HI for the recreational child was also below 1. Future pathway HIs for the on-site/recreational adult are below the reference level of 1. Total exposure HI for the on-site/recreation adult are also below 1.

Table 4-104
Current Hazard Index Estimates for the On-site Adult - Site 8
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of soils.			
Antimony	1E-02		
Lead	0E+00		
		1E-02	
Exposure Pathway: Dermal contact with soils.			
Antimony	2E-01		
Lead	4E-03		
		2E-01	
On-site Adult - Total Current Hazard Index			
			2E-01

Table 4-105
Future Carcinogenic Risk Estimates for the Recreational Child - Site 8
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Ingestion of groundwater.			
Tetrachloroethylene	9E-08		
		9E-08	
Exposure Pathway: Dermal contact with groundwater.			
Tetrachloroethylene	6E-08		
		6E-08	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater.			
Tetrachloroethylene	1E-09		
		1E-09	
Exposure Pathway: Ingestion of soils.			
Antimony	0E+00		
Lead	0E+00		
		0E+00	
Exposure Pathway: Dermal contact with soils.			
Antimony	0E+00		
Lead	0E+00		
		0E+00	
Recreational Child - Total Future Cancer Risk			
			1E-07

Table 4-106
Future Carcinogenic Risk Estimates for the On-site/Recreational Adult - Site 8
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Ingestion of groundwater.			
Tetrachloroethylene	3E-07		
		3E-07	
Exposure Pathway: Dermal contact with groundwater.			
Tetrachloroethylene	3E-07		
		3E-07	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater.			
Tetrachloroethylene	4E-09		
		4E-09	
Exposure Pathway: Ingestion of soils.			
Antimony	0E+00		
Lead	0E+00		
		0E+00	
Exposure Pathway: Dermal contact with soils.			
Antimony	0E+00		
Lead	0E+00		
		0E+00	
On-site/Recreational Adult - Total Future Cancer Risk			
			7E-07

Table 4-107
Estimate of Future Noncarcinogenic Effects for the Recreational Child - Site 8
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Risk	Total Exposure Hazard Risk
Exposure Pathway: Ingestion of groundwater.			
Tetrachloroethylene	8E-04		
		8E-04	
Exposure Pathway: Dermal contact with groundwater.			
Tetrachloroethylene	5E-04		
		5E-04	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater.			
Tetrachloroethylene	3E-04		
		3E-04	
Exposure Pathway: Ingestion of soils.			
Antimony	2E-02		
Lead	0E+00		
		2E-02	
Exposure Pathway: Dermal contact with soils.			
Antimony	5E-02		
Lead	4E-03		
		5E-02	
Recreational Child - Total Future Hazard Risk			
			8E-02

Table 4-108
Estimate of Future Noncarcinogenic Effects for the On-site/Recreational Adult - Site 8
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Risk	Total Exposure Hazard Risk
Exposure Pathway: Ingestion of groundwater.			
Tetrachloroethylene	2E-03		
		2E-03	
Exposure Pathway: Dermal contact with groundwater.			
Tetrachloroethylene	2E-03		
		2E-03	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater.			
Tetrachloroethylene	6E-04		
		6E-04	
Exposure Pathway: Ingestion of soils.			
Antimony	1E-02		
Lead	0E+00		
		1E-02	
Exposure Pathway: Dermal contact with soils.			
Antimony	3E-01		
Lead	4E-03		
		3E-01	
On-site/Recreational Adult - Total Future Hazard Index			
			3E-01

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Table 4-109
Estimate of Future Noncarcinogenic Effects for the Excavation Worker - Site 8
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Risk	Total Exposure Hazard Risk
Exposure Pathway: Ingestion of soils.			
Antimony	6E-02		
Lead	0E+00		
		6E-02	
Exposure Pathway: Dermal contact with soils.			
Antimony	2E-01		
Lead	4E-03		
		2E-01	
Exposure Pathway: Inhalation of fugitive dust.			
Antimony	2E-01		
Lead	0E+00		
		2E-01	
Excavation Worker - Total Future Hazard Index			
			5E-01

SUM8S.WB1/ 940127

No pathway subchronic HI above 1 is calculated for the excavation worker. Total exposure HI is also below 1.

4.13.5 Risk Assessment Uncertainties

This section presents a discussion of uncertainties involved in the process of quantifying risk for human receptors. Uncertainties involved in the exposure assessment, toxicity assessment, HI and cancer risk estimation are discussed separately.

4.13.5.1 Exposure Assessment Uncertainties

Uncertainty in the exposure assessment is a function of the completeness of site data, assumptions that simplify and approximate actual current or future site conditions, and professional judgement used in developing and evaluating various parameters. Assumptions and inferences must be made to develop exposure scenarios. These assumptions and inferences introduce uncertainties into the exposure assessment.

The exposure scenarios presented are conservative, and overestimate rather than underestimate exposure. The approach is conservative and is designed to compensate for uncertainties inherent in the exposure assessment. The use of very conservative health-protective exposure factors in the exposure assessment process results in final intake values that are extremely conservative. RME chronic intake values may be overestimated by one to two orders of magnitude.

In quantifying exposure levels, the chemicals are assumed to be uniformly distributed over the defined area, thus resulting in a uniform exposure level. Chemical analytical data were obtained from a directed sampling program, i.e., sampling locations were generally selected on the basis of where contaminants were expected to be present. Sampling zones found to be free of contamination received less investigation. This sampling scheme tends to greatly overestimate the overall chemical concentrations at a site.

One of the assumptions used in the exposure assessment is that the current chemical concentrations in groundwater are assumed to remain constant over exposure pathway duration and that the transport mechanisms are assumed to have reached equilibrium. This means that the levels will not decrease due to the exhaustion of the contaminant sources over the assumed exposure periods. The result of this assumption is a probable overestimation of groundwater exposure point concentrations because contaminant sources will not likely remain constant over time.

The model used for inhalation of fugitive dust assumes no dilution of particulates over distance and assumes all particles are respirable which results in an overestimation of risk.

Finally, the assumptions is made that human exposure remains constant over the lifetime of an individual. In actuality, lifestyle changes due to age and actual residence time will alter the projected exposure durations. Movement of individuals in and out of the potentially exposed community also affects exposure duration.

4.13.5.2 Toxicity Assessment

RfDs developed by the EPA are generally considered to have uncertainty spanning an order of magnitude or more. Consequently, total exposure HIs for the resident child and adult may be estimated high or low by an order of magnitude or more.

Low confidence by EPA in an RfD value, indicates high uncertainty in the accuracy of the toxicity value. High uncertainty indicates that the value may change in the future if additional toxicity data were to become available. Conversely, high confidence by the EPA in an RfD indicates low uncertainty in the accuracy of the toxicity value.

SFs developed by the EPA are generally conservative and represent the upper bound limit of the probability of a cancer response. Thus, the actual cancer risk due to exposure to the chemicals of concern is likely to be lower than the estimated risk.

A second area of uncertainty is those chemicals which were not included in the quantitative assessment because of lack of carcinogenic or noncarcinogenic toxicity values. Chemical lacking RfD values include lead and those lacking SFs include antimony and styrene. The total risk without considering these chemicals is underestimated.

4.13.5.3 Risk Estimates

The uncertainties involved in combining the pathways are considered minimal, as the inhalation dermal and ingestion pathways could reasonably contribute to exposure of the same individual over the same period of time. Assumption of dose accumulation ignores possible synergisms and antagonisms among chemicals, but does prevent under-estimation of risks.

4.13.6 Conclusions

A summary of current and future carcinogenic and noncarcinogenic risks was presented previously in Tables 4-104 through 4-109.

Currently, exposure to contaminants of concern at Site 8 could occur only through exposure to soil. Future exposure could occur through soil or groundwater exposure.

Per MDNR guidance, a cancer risk exceeding 1×10^{-6} is an unacceptable human health risk (EPA, 1989). No SFs were available for antimony and lead; therefore, no current cancer risk was computed for the on-site adult. Acceptable levels of future carcinogenic risk were determined for the recreational child, on-site/recreational adult, and excavation worker.

For non carcinogenic effects, EPA guidance considers a HI greater than 1 to indicate potential for adverse noncarcinogenic health effect (EPA, 1989b). It has been demonstrated that the current future HIs for the adult, child, and excavation worker are below the reference level of 1, indicating a low potential for adverse noncarcinogenic effects.

No data is available regarding the deeper limestone aquifer. The potential for contaminants to migrate from the shallow aquifer to the deeper aquifer and contaminate on-site or off-site drinking wells was qualitatively assessed. No continuous clay layer which could act as an aquitard was present between the two aquifers, consequently, the potential exists for contaminants to migrate vertically into the limestone aquifer if a vertical hydraulic gradient exists between the two aquifers. PCE is a class B2 carcinogen and could pose a health threat if exposure occurs.

4.14 SITE 9 RADAR TOWER SITE RISK ASSESSMENT

A baseline risk assessment was conducted for the Site 9 Radar Tower Site to estimate the health risk for human receptors.

Section 4.14.1 identifies the chemicals of potential concern. Section 4.14.2 present an exposure assessment for human receptors. The toxicity assessment for chemicals of potential concern was previously presented in Section 4.6. The risk characterization for carcinogenic and noncarcinogenic effects is presented in Section 4.14.4. Uncertainties in the human health assessment are discussed in Section 4.14.5. Section 4.14.6 presents a summary of total carcinogenic risk and the total exposure HIs for on-site adults and children.

4.14.1 Identification of Chemicals

Chemicals of potential concern at Site 9 were selected for soils and groundwater through the process outlined in Section 4.2. The results of the selection process are presented in Section 4.14.1.1 and 4.14.1.2.

4.14.1.1 Selection of Chemicals of Potential Concern within the Soil

Tables 3-22 and 3-23 present a summary of the validated surface and subsurface soil data collected during the RI. The complete data set is included in Appendix L. Additionally, soil data from the SI is included in Appendix N but is not used in the estimate of risk. Tables 4-110 and 4-111 presents a summary of the range of detected concentrations, the number of detections, and the criteria used in the evaluation.

No chemicals were detected in the RI data at levels above the Act 307 Type B cleanup criteria and no potential chemicals of concern were identified.

4.14.1.2 Selection of Chemicals of Potential Concern within the Shallow Aquifer

Table 3-24 presents a summary of the validated groundwater data collected during the RI. Historical groundwater data from Site 9 is included in Appendix N and O. Table 4-112 presents a summary of the range of detected concentrations, the number of detections, and the criteria used in the evaluation.

Table 4-110 Data Summary Table: Surface Soil, Site 9 - Radar Tower Site
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/kg)	Act 307* Cleanup Criteria (µg/kg)
Aromatic Volatiles (ppb)			
1,4-Dichlorobenzene	2 / 6	0.099 / 2.6	30
Methyl-t-Butyl Ether	1 / 6	0.56 / 0.56	4600
Semivolatiles (ppb)			
bis(2-Ethylhexyl)phthalate	2 / 6	52 / 150	92000(G)
Metals (ppb)			
Aluminum	5 / 5	1600000 / 4220000	6900000
Arsenic	1 / 6	1100 / 1100	5800
Calcium	3 / 5	230000 / 2570000	
Cadmium	1 / 6	590 / 590	1200
Chromium	6 / 6	3300 / 5400	18000
Copper	1 / 6	7800 / 7800	2000
Iron	5 / 5	2290000 / 3390000	12000000
Lead	6 / 6	1200 / 2600	21000
Manganese	5 / 5	21100 / 51600	440000
Magnesium	2 / 5	533000 / 813000	
Vanadium	4 / 5	5400 / 8500	1200
TPH (ppb)			
Total Petroleum Hydrocarbons	6 / 6	14100 / 21500	NA

* Refer to Table 4-1 for explanation of Act 307 footnotes.
NA - Not Available.

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Table 4-111 Data Summary Table: Subsurface Soil, Site 9 - Radar Tower Site
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations (µg/kg)	Range of Background Concentrations (µg/kg)	Act 307* Cleanup Criteria (µg/kg)
Aromatic Volatiles (ppb)				
1,2-Dichlorobenzene	1 / 8	2.1 / 2.1	ND	12000
1,4-Dichlorobenzene	1 / 8	1.9 / 1.9	ND	30
Chlorobenzene	1 / 8	1.6 / 1.6	ND	2600
Methyl-t-Butyl Ether	1 / 8	0.54 / 0.54	ND	4600
Halogenated Volatiles (ppb)				
1,1,1-Trichloroethane	1 / 8	0.13 / 0.13	ND	4000
Methylene chloride	1 / 8	9.3 / 9.3	ND	92
Semivolatiles (ppb)				
bis(2-Ethylhexyl)phthalate	3 / 8	35 / 130	ND	92000{G}
Metals (ppb)				
Aluminum	7 / 7	639000 / 1600000	/	6900000
Calcium	6 / 7	26800000 / 35700000	/	
Chromium	8 / 8	1800 / 5300	/	18000
Copper	1 / 8	2700 / 2700	/	32000
Iron	7 / 7	1220000 / 2700000	/	12000000
Lead	8 / 8	670 / 1400	/	21000
Manganese	7 / 7	33900 / 58500	/	440000
Magnesium	7 / 7	804000 / 6250000	/	
Vanadium	1 / 7	6200 / 6200	/	1200
TPH (ppb)				
Total Petroleum Hydrocarbons	8 / 8	8700 / 21400	ND	NA

* Refer to Table 4-1 for explanation of Act 307 footnotes.
NA - Not Available.

wp/t4-111.775-08/15/95

Table 4-112 Data Summary Table: Groundwater, Site 9 - Radar Tower Site
MIANG, Alpena CRTC, Alpena, Michigan

	Frequency of Detection	Range of Detected Concentrations ($\mu g/l$)	Background Concentrations ($\mu g/l$)	Act 307* Cleanup Criteria ($\mu g/l$)
Aromatic Volatiles ($\mu g/l$)				
1,2-Dichlorobenzene	1 / 6	3.6 / 3.6	ND	600
1,2-Dimethylbenzene	1 / 6	860 / 860	ND	280{R}
1,3-Dimethylbenzene	1 / 1	800 / 800	ND	280{R}
1,4-Dichlorobenzene	1 / 6	18 / 18	ND	1.5
Benzene	1 / 6	3.9 / 3.9	ND	1.2
Chlorobenzene	1 / 6	0.93 / 0.93	ND	130
Ethylbenzene	1 / 6	1.4 / 1.4	ND	74{R}
Methyl-t-Butyl Ether	1 / 6	1.3 / 1.3	ND	230
Styrene	1 / 6	0.78 / 0.78	ND	1.2
Toluene	1 / 6	3.1 / 3.1	ND	790{R}
Halogenated Volatiles ($\mu g/l$)				
Chloroform	2 / 6	0.13 / 0.16	ND	5.6
Methylene chloride	1 / 6	0.53 / 0.53	ND	4.6
Tetrachloroethylene	3 / 6	1 / 1.7	ND	0.7
Trichloroethylene	1 / 6	0.6 / 0.6	ND	2.2
Low Con. Semivolatiles ($\mu g/l$)				
2,4-Dimethylphenol	1 / 6	25 / 25	ND	350
2-Methylnaphthalene	1 / 6	47 / 47	ND	ID
4-Methylphenol	1 / 6	2 / 2	ND	35
Acenaphthene	1 / 6	1 / 1	ND	1200
Fluorene	1 / 6	0.8 / 0.8	ND	840
Naphthalene	1 / 6	48 / 48	ND	250
Phenanthrene	1 / 6	0.8 / 0.8	ND	25
Metals ($\mu g/l$)[1)]				
Arsenic	5 / 6	10.8 / 45.9	/	
Beryllium	1 / 6	2.7 / 2.7	/	
Chromium	5 / 6	8.2 / 78.8	/	
Copper	5 / 6	56.8 / 90.1	/	
Copper, Dissolved	1 / 6	5.7 / 5.7	/	1000{R}
Lead	5 / 6	55.1 / 267	/	
Lead, Dissolved	1 / 6	15.9 / 15.9	/	4{C,O}
Nickel	3 / 6	38.2 / 74.7	/	
Zinc	2 / 6	67.2 / 176	/	
Zinc, Dissolved	2 / 6	5.6 / 6.3	/	2300{C}

* Refer to Table 4-1 for explanation of Act 307 footnotes.
1) Criteria is presented for dissolved metals only.

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The following chemicals were detected at levels above Act 307 Type B cleanup criteria and are considered chemicals of potential concern:

- Tetrachloroethylene
- 1,4-Dichlorobenzene
- Benzene
- 2 Methylnapthalene
- Lead, dissolved.

4.14.2 Exposure Assessment

The purpose of the exposure assessment is to estimate the type and magnitude of human receptor exposure to chemicals of potential concern resulting from Site 9 activities. The following exposure assessment components are evaluated in this section:

- Characterization of the exposure setting (Section 4.14.2.1)
- Identification of exposure pathways/receptors (Section 4.14.2.2)
- Estimation of chemical concentrations at receptors (Section 4.14.2.3)
- Estimation of on-site child and adult intake values (Section 4.14.2.4).

4.14.2.1 Characterization of the Exposure Setting

Site 9 is the area surrounding the AGE shop (Figure 1-11). The site is grass covered with scattered trees. A wooded area lies to the north of the site. The soils consist of a medium-grained, quartz sand deposit. The shallow aquifer is approximately 18 m (60 ft) thick. A small lens of clay 0.3 m (1 ft) thick was observed above the Traverse Group Limestone in boring RT9SB13.

The depth to shallow groundwater at Site 9 is 4.3 to 7.3 m (14 to 24 ft) bgs. Flow within the shallow aquifer is north toward the sinkhole. The sinkhole is approximately 305 m (1,000 ft) from Site 9. No recreational use of the sinkhole occurs by facility personnel or visitors. A vertical component of flow may exist within the surficial aquifer. Groundwater elevations in a nested well pair (RT9MW4 and RT9MW5) showed a 12 cm (0.40 ft) difference in hydraulic head, indicating that the head in the shallow portion of the aquifer is higher than the head in the deeper portion of the aquifer. The shallow aquifer at Site 9 likely has sufficient capacity to support drinking wells.

No data were collected in the limestone aquifer; therefore, the direction of groundwater flow in the limestone aquifer is unknown at this time. Off-site residential wells are present to the north, south, and east of the Alpena CRTC. All residential wells are completed in the limestone aquifer.

The drinking water supply for the main portion of Alpena CRTC consists of three on-site production wells. These wells are located southwest of Site 9. PW1, the main production well, is screened in the limestone aquifer. PW2 is screened in both the shallow and limestone aquifers and, consequently, provides a conduit for contaminant migration. Shallow groundwater at Site 9 flows north to the sinkhole; consequently, little potential exists for contaminants in the shallow groundwater at Site 9 to migrate to PW2.

4.14.2.2 Identification of Exposure Pathways/Receptors

The ANG holds the lease on the land until the year 2039; therefore, the current land-use has been evaluated for future exposure. Full-time personnel are located in the AGE shop. No training activities occur at this site.

An alternate future land-use which will be considered is recreational use of the area. Residential land-use is considered highly improbable due to the location of the site in a rural area with low growth.

The following potential current exposure pathways and receptors were identified:

- Dermal contact with soils by facility personnel or construction workers
- Ingestion of contaminated groundwater by off-site residents
- Inhalation of vapor phase chemicals from domestic groundwater use by on-site personnel
- Dermal absorption of groundwater during domestic use by on-site personnel
- Ingestion of contaminated groundwater by on-site personnel
- Inhalation of vapor phase chemicals from domestic groundwater use by off-site residents
- Dermal absorption of groundwater by off-site residents.

The following future potential exposure pathways and receptors were identified:

- Future ingestion of contaminated fish caught in the sinkhole by adults and children
- Future dermal absorption of contaminated surface water by adults and children playing in the sinkhole

- Future incidental ingestion of contaminated surface water by adults and children playing in the sinkhole
- Future dermal absorption of contaminated bedrock groundwater by on-site personnel
- Future inhalation of vapor phase chemicals from domestic bedrock groundwater use by on-site personnel
- Future ingestion of contaminated bedrock groundwater by on-site personnel
- Future inhalation of vapor phase chemicals from domestic bedrock groundwater use by off-site residents
- Future ingestion of contaminated shallow groundwater by on-site personnel
- Future inhalation of vapor phase chemicals from shallow groundwater domestic use by on-site personnel
- Future dermal absorption of shallow groundwater by on-site personnel.

Because no chemicals of concern were identified in the soils at Site 9, the potential current pathway, dermal contact with soils is considered incomplete and is eliminated from further consideration

Current and future potential pathways involving on-site production well groundwater are addressed in Section 4.7. Future pathways involving the sinkhole are addressed in Section 4.10. Based on the elimination of all incomplete pathways, and those completed pathways which are considered elsewhere, Table 4-113 presents the current and future exposure pathways which are considered complete.

4.14.2.3 Estimation of Chemical Concentrations at Receptors

No data currently exist for off-site residential well water; therefore, these pathways will be addressed qualitatively in Section 4.14.6.

Future concentrations of chemicals of potential concern in shallow groundwater were assumed to be equal to the current concentration. Table 4-114 presents the minimum, maximum and 95 percent UCLs for the chemicals of concern. No data currently exist for off-site residential groundwater; therefore, these future pathways will be addressed qualitatively.

4.14.2.4 Estimation of On-Site Child and Adult Intake Values

On-site child and adult CDI for carcinogenic effects and subchronic noncarcinogenic effects were estimated for exposure pathways identified in Table 4-112. Tables 4-115 through 4-117 present the formulas and assumptions used to model current and future RME intake values for each identified exposure pathway. Standard default exposure factors were used to estimate

Table 4-113 Current and Future Exposure Pathways – Site 9
MIANG, Alpena CRTC, Alpena, Michigan

Receptor Population	Exposure Point	Exposure Pathway
Current Land-use		
Adult and Child	off-site	Ingestion of contaminated groundwater from bedrock wells
Adult and Child	off-site	Dermal absorption of contaminated groundwater
Adult and Child	off-site	Inhalation of vapor phase chemicals from domestic groundwater use
Future Land-use		
Adult and Child	on-site	Ingestion of contaminated groundwater from future shallow aquifer wells
Adult and Child	off-site	Ingestion of contaminated groundwater from bedrock wells
Adult and Child	off-site	Inhalation of vapor phase chemicals from groundwater use
Adult and Child	on-site	Inhalation of vapor phase chemicals from future domestic shallow wells
Adult and Child	on-site	Dermal absorption of contaminated groundwater from future shallow aquifer wells
Adult and Child	off-site	Dermal absorption of contaminated groundwater

intake where applicable; acceptable exposure factor references are listed for those standard default exposure factors. Reasonable assumptions were made to quantify site-specific exposure factors. Site-specific assumptions were necessary to estimate exposure frequencies for children. Children of visiting or full-time employees may use the on-site facilities during the weekends. It was assumed that children would be present on-site 6 months per year for 8 days per months for a total of 48 days per year. It was further assumed that these children would be present through the childhood years (0-15 years) for an exposure duration of 15 years. These assumptions were assumed to be applicable for recreational land-use also. A worst case scenario for the adult was evaluated. This scenario assumes that an adult works at the recreational area during the week and participates in recreational activities on the weekend.

Using the exposure intake models presented in Tables 4-115 through 4-117, current and future chemical intake values were estimated for the potential receptors previously identified. Table 4-118 presents a summary of the exposure assessment for future land-use at Site 9. Detailed calculations are presented in Appendix W.

4.14.3 Toxicity Assessments

Toxicity profiles for chemicals of potential concern were presented previously in section 4.4.1, Toxicity Profiles. Section 4.4.2, Toxicity Values, presents the toxicity values for chemicals

Table 4- 114
Reasonable Maximum Exposure Concentrations - Site 9
MIANG, Alpena CRTC, Alpena, Michigan

Matrix	Compound	Units	Arithmetic Mean	N	Maximum Value	Minimum Value	95% UCL
GROUNDWATER	Tetrachloroethylene	ug/l	0.78	6	1.7	0.15	1.37
GROUNDWATER	2-Methylnaphthalene	ug/l	9.92	6	47	2.50	24.86
GROUNDWATER	1,4-Dichlorobenzene	ug/l	3.66	5	18	0.08	11.30
GROUNDWATER	Benzene	ug/l	0.80	6	3.9	0.18	2.05
GROUNDWATER	Lead, Dissolved	ug/l	3.48	6	15.9	1.00	8.49

If the 95% UCL is greater than the maximum value, then the maximum value is the reasonable maximum exposure concentration.

Table 4-115 Model for Estimating Future Chemical Intake by Adults and Children through Drinking Water Ingestion from the Shallow Aquifer - Site 9 MIANG, Alpena CRTC, Alpena, Michigan

$$CDI\ (mg/Kg\text{-}day) = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

where:

CDI	=	Chronic Daily Intake (mg/kg-day), representing the reasonable maximum exposure (RME).
CW	=	Chemical Concentration in Groundwater (mg/ℓ).
IR	=	Drinking Water Ingestion Rate (ℓ/day).
EF	=	Exposure Frequency (days/year).
ED	=	Exposure Duration (years).
BW	=	Body Weight (kg).
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	On-site/Recreational Adults[1]	Child
Ingestion Rate (IR) (L/day)	2	2[2]
Exposure Frequency (EF) (days/yr)	298	48[3]
Exposure Duration (ED) (years)	25	15[3]
Body Weight (kg)	70	27[2]
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) All values from U.S. Environmental Protection Agency, 1991.
2) Site specific assumption - see Section 4.13.2.4.
3) U.S. Environmental Protection Agency 1989a.

Table 4-116 Model for Estimating Future Chemical Absorbed Dose by Adults and Children through Dermal Contact with Chemicals in Shallow Aquifer Groundwater - Site 9 MIANG, Alpena CRTC, Alpena, Michigan

$$Absorbed\ Dose\ (mg/kg\text{-}day) = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

where:

CW	=	Chemical Concentration in Water (mg/ℓ).
SA	=	Skin Surface Area Available for Contact (cm^2).
PC	=	Chemical-specific Dermal Permeability Constant (cm/hr) default 8.4×10^{-4}
ET	=	Exposure Time (hours/day).
EF	=	Exposure Frequency (days/years)
ED	=	Exposure Duration (years)
CF	=	Volumetric Conversion Factor for Water (1 liter/1000 cm^3)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged, in days).

Assumptions:	Adult	Child
CW[5]		
Skin Surface Area (cm^2)[5]	19,400[1]	13,300[1]
Dermal Permeability Constant (cm/hr)	8.4×10^{-4} [2]	8.4×10^{-4} [2]
Exposure Time (hours/day)	.25	.25[4]
Exposure Frequency (days/yr)	298[3]	48[3]
Exposure Duration (years)	25[3]	15[3]
Body Weight (kg)	70	27[2]
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) U.S. Environmental Protection Agency, 1989b – Child is average for ages 0-15.
2) U.S. Environmental Protection Agency, 1989.
3) Site specific assumption – See Section 4.8.2.4
4) Assumes a total exposure time of 25 minutes per day for domestic use of groundwater (SEAM 1988)
5) Chemical-specific permeability constants were used when available: PCE 4×10^{-1} (Tab 5-3, EPA, 92), 2-methylnapthlenene 1×10^{-3}, (Tab 5-3, EPA 92), 1,4 dichlorobenzene 6.2×10^{-2} (Tab 5-7, EPA 92), benzene 1×10^{-1}, (Tab 5-3, EPA, 92) lead 4×10^{-6} (Tab 5-3, EPA, 92).

Table 4-117 Model for Estimating Future Chemical Intake by Adults and Children through Inhalation of Vapor Phase Chemicals during Showering - Site 9 MIANG, Alpena CRTC, Alpena, Michigan

$$Intake\ (mg/Kg\text{-}day) = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$$

where:

- CA = Contaminant Concentration in Air (mg/m^3)
- IR = Inhalation Rate (m^3/hour)
- ET = Exposure Time (hours/day)
- EF = Exposure Frequency (days/year)
- ED = Exposure Duration (years)
- BW = Body Weight (kg)
- AT = Averaging Time (period over which exposure is averaged, in days).

$$CA\ (contaminant\ concentration\ in\ air,\ mg/m^3) = \frac{(CA_{max}\ /\ 2)\ t_1 + CA_{max}\ t_2}{t_1 + t_2}\ (1),$$

$$Where:\ CA_{max} = \frac{C_w\ f\ F_w\ t_1}{V_a}\ (1)$$

Where:

- C_w = The arithmetic mean or the 95% upper confidence limit (UCL) of the arithmetic mean of the contaminant concentration in shower water (mg/ℓ). Contaminant concentrations in groundwater are used as shower water concentrations.
- f = The fraction volatized (unitless) is 0.7 (i.e., the mean of the range of 0.5 to 0.9) (Andelman, 1990).
- F_w = The water flow rate (ℓ/hr) is 750 L/hr (i.e., the mean of the range 500 to 1,000 l/hr) (Wang, 1992).
- t_1 = The duration period for showering (hr) is 0.25 hr (SEAM, 1988).
- t_2 = The duration period for the time after showering is 0.35 hr (i.e., the mean of the range of 0.2 to 0.5 hr) (Wang, 1992).
- V_a = The bathroom volume (m^3) is 11 m^3 (i.e., the mean of the range of 6 to 16 m^3) (Wang, 1992).

(1) Reference: Wang, 1992.

Assumptions:	On-Site/Recreational Adult	Child
Inhalation Rate (m^3/hr)	0.6[1]	0.6[1]
Exposure Time (minutes)	7[1]	7[1]
Exposure Frequency (days/year)	298[3]	48[3]
Exposure Duration (years)	25[2]	15[3]
Body Weight (kg)	70[2]	27[4]
Averaging Time (years), (noncarcinogenic)	25	15

Notes:
1) U.S. Environmental Protection Agency, 1989b.
2) U.S. Environmental Protection Agency, 1991.
3) Site specific assumption – see Section 4.13.2.4.
4) U.S. Environmental Protection Agency, 1989a.

Table 4-118
Exposure Assessment - Future Land Use - Site 9
MIANG, Alpena CRTC, Alpena, Michigan

Population	Exposure Pathway	Chemical	Chronic Daily Intakes (CDI)(mg/kg-da Carcinogenic Effects	Noncarcinogenics Effects
On-Site/Recreational Adu	Ingestion of groundwater from shallow aquifer wells	Tetrachloroethylene	1.1E-05	3.2E-05
		2-Methylnaphthalen	2.1E-04	5.8E-04
		1,4-Dichlorobenzen	9.4E-05	2.6E-04
		Benzene	3.2E-05	9.1E-05
		Lead, Dissolved	7.1E-05	2.0E-04
	Dermal contact with groundwater from shallow aquifer wells	Tetrachloroethylene	1.1E-05	3.1E-05
		2-Methylnaphthalen	5.0E-07	1.4E-06
		1,4-Dichlorobenzen	1.9E-07	5.4E-07
		Benzene	7.8E-06	2.2E-05
		Lead, Dissolved	6.9E-10	1.9E-09
	Inhalation of vapor-phase chemicals relea from groundwater during domestic use	Tetrachloroethylene	3.9E-06	1.1E-05
		2-Methylnaphthalen	0.0E+00	0.0E+00
		1,4-Dichlorobenzen	3.2E-05	9.0E-05
		Benzene	1.1E-05	3.1E-05
		Lead, Dissolved	0.0E+00	0.0E+00
Recreational Child	Ingestion of groundwater from shallow aquifer wells	Tetrachloroethylene	2.9E-06	1.3E-05
		2-Methylnaphthalen	5.2E-05	2.4E-04
		1,4-Dichlorobenzen	2.4E-05	1.1E-04
		Benzene	8.1E-06	3.8E-05
		Lead, Dissolved	1.8E-05	8.3E-05
	Dermal contact with groundwater from shallow aquifer wells	Tetrachloroethylene	1.9E-06	8.9E-06
		2-Methylnaphthalen	8.6E-08	4.0E-07
		1,4-Dichlorobenzen	3.3E-08	1.5E-07
		Benzene	1.4E-06	6.3E-06
		Lead, Dissolved	1.2E-10	5.5E-10
	Inhalation of vapor-phase chemicals relea from groundwater during domestic use	Tetrachloroethylene	9.7E-07	4.5E-06
		2-Methylnaphthalen	0.0E+00	0.0E+00
		1,4-Dichlorobenzen	8.0E-06	3.7E-05
		Benzene	2.8E-06	1.3E-05
		Lead, Dissolved	0.0E+00	0.0E+00

SITE9A.WB1/ 940127

of potential concern.

4.14.4 Risk Characterization

The potential risks associated with the chemicals of concern were evaluated as outlined in Section 4.5. Section 4.14.4.1 presents the risk characterization for current land-use and Section 4.14.4.2 presents the future land-use risk characterization.

4.14.4.1 Current Land-Use Conditions

No current land-use risk characterizations were quantitatively evaluated. Off-site receptors are evaluated qualitatively in Section 4.14.6.

4.14.4.2 Future Land-Use Conditions

Tables 4-119 and 4-120 present cancer risk estimates for the on-site child and adult, respectively. Detailed calculations are presented in Appendix W. Each table presents chemical-specific cancer risks, pathway cancer risks, and total exposure cancer risk for the on-site child and adult.

Future carcinogenic risk above the reference level of 1×10^{-6} but of the same order of magnitude, was calculated for one exposure pathway for the on-site/recreational adult; ingestion of groundwater from shallow auqifer wells. 1,4 dichlorobenzene contributes 40% of the risk for groundwater ingestion.

No pathways above the 1×10^{-6} reference level were calculated for the recreational child. Total exposure cancer risk is equal to, but does not exceed, 1×10^{-6}.

Tables 4-121 and 4-122 present chronic HI estimates for the on-site child and adult, respectively. Detailed calculations are presented in Appendix W. Each table presents chemical-specific HQs, pathway HIs, and total exposure HIs for the on-site child and adult.

All future pathway HIs were below the reference level of 1 and total exposure HI was also below 1 for both the adult and child receptors, indicating a low potential for adverse noncarcinogenic health effects.

4.14.5 Risk Assessment Uncertainties

This section presents a discussion of uncertainties involved in the process of quantifying risk for human receptors. Uncertainties involved in the exposure assessment, toxicity assessment, HI, and cancer risk estimation are discussed separately.

Table 4-119
Future Carcinogenic Risk Estimates for the Recreational Child - Site 9
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Ingestion of groundwater from shallow aquifer wells			
Tetrachloroethylene	1E-07		
2-Methylnaphthalene			
1,4-Dichlorobenzene	6E-07		
Benzene	2E-07		
Lead, Dissolved			
		9E-07	
Exposure Pathway: Dermal contact with groundwater from shallow aquifer wells			
Tetrachloroethylene	1E-07		
2-Methylnaphthalene			
1,4-Dichlorobenzene	8E-10		
Benzene	4E-08		
Lead, Dissolved			
		1E-07	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater during domestic use			
Tetrachloroethylene	2E-09		
2-Methylnaphthalene			
1,4-Dichlorobenzene	3E-07		
Benzene	4E-08		
Lead, Dissolved			
		4E-07	
Recreational Child - Total Future Cancer Risk			
			1E-06

S9ASUMMA.WB1/940127

Table 4-120
Future Carcinogenic Risk Estimates for the On-Site/Recreational Adult - Site 9
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Carcinogenic Risk	Total Pathway Carcinogenic Risk	Total Exposure Carcinogenic Risk
Exposure Pathway: Ingestion of groundwater from shallow aquifer wells			
Tetrachloroethylene	6E-07		
2-Methylnaphthalene			
1,4-Dichlorobenzene	2E-06		
Benzene	9E-07		
Lead, Dissolved			
		4E-06	
Exposure Pathway: Dermal contact with groundwater from shallow aquifer wells			
Tetrachloroethylene	6E-07		
2-Methylnaphthalene			
1,4-Dichlorobenzene	5E-09		
Benzene	2E-07		
Lead, Dissolved			
		8E-07	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater during domestic use			
Tetrachloroethylene	7E-09		
2-Methylnaphthalene			
1,4-Dichlorobenzene	1E-06		
Benzene	2E-07		
Lead, Dissolved			
		1E-06	
On-site/Recreational Adult - Total Future Cancer Risk			
			6E-06

Major Pathway Contributing to Risk	Major Chemicals Contributing to Pathway Risk	Chemical Percent Contribution
Ingestion of Groundwater from Shallow Wells	1,4-Dichlorobenzene	50

S9ASUMMA.WB1/940127

Table 4-121
Estimate of Future Noncarcinogenic Effects for the Recreational Child - Site 9
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of groundwater from shallow aquifer wells			
Tetrachloroethylene	1E-03		
2-Methylnaphthalene	8E-03		
1,4-Dichlorobenzene	0E+00		
Benzene	0E+00		
Lead, Dissolved	0E+00		
		9E-03	
Exposure Pathway: Dermal contact with groundwater from shallow aquifer wells			
Tetrachloroethylene	9E-04		
2-Methylnaphthalene	8E-05		
1,4-Dichlorobenzene	0E+00		
Benzene	0E+00		
Lead, Dissolved	0E+00		
		1E-03	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater during domestic use			
Tetrachloroethylene	5E-04		
2-Methylnaphthalene	0E+00		
1,4-Dichlorobenzene	2E-04		
Benzene	0E+00		
Lead, Dissolved	0E+00		
		6E-04	
Recreational Child - Total Future Hazard Index			
			1E-02

Table 4-122
Estimate of Future Noncarcinogenic Effects for the On-site/Recreational Adult - Site 9
MIANG, Alpena CRTC, Alpena, MI

Chemical	Chemical-specific Hazard Quotient	Total Pathway Hazard Index	Total Exposure Hazard Index
Exposure Pathway: Ingestion of groundwater from shallow aquifer wells			
Tetrachloroethylene	3E-03		
2-Methylnaphthalene	2E-02		
1,4-Dichlorobenzene	0E+00		
Benzene	0E+00		
Lead, Dissolved	0E+00		
		2E-02	
Exposure Pathway: Dermal contact with groundwater from shallow aquifer wells			
Tetrachloroethylene	3E-03		
2-Methylnaphthalene	3E-04		
1,4-Dichlorobenzene	0E+00		
Benzene	0E+00		
Lead, Dissolved	0E+00		
		3E-03	
Exposure Pathway: Inhalation of vapor-phase chemicals released from groundwater during domestic use			
Tetrachloroethylene	1E-03		
2-Methylnaphthalene	0E+00		
1,4-Dichlorobenzene	4E-04		
Benzene	0E+00		
Lead, Dissolved	0E+00		
		2E-03	
On-site/Recreational Adult - Total Future Hazard Index			
			3E-02

4.14.5.1 Exposure Assessment Uncertainties

Uncertainty in the exposure assessment is a function of the completeness of site data, assumptions that simplify and approximate actual current or future site conditions, and professional judgement used in developing and evaluating various parameters. Assumptions and inferences must be made to develop exposure scenarios. These assumptions and inferences introduce uncertainties into the exposure assessment.

The exposure scenarios presented are conservative, and overestimate rather than underestimate exposure. The approach is conservative and is designed to compensate for uncertainties inherent in the exposure assessment. The use of very conservative health-protective exposure factors in the exposure assessment process results in final intake values that are extremely conservative. RME chronic intake values may be overestimated by one to two orders of magnitude.

In quantifying exposure levels, the chemicals are assumed to be uniformly distributed over the defined area, thus resulting in a uniform exposure level. Chemical analytical data were obtained from a directed sampling program, i.e., sampling locations were generally selected on the basis of where contaminants were expected to be present. Sampling zones found to be free of contamination received less investigation. This sampling scheme tends to greatly overestimate the overall chemical concentrations at a site.

One of the assumptions used in the exposure assessment is that the current chemical concentrations in groundwater are assumed to remain constant over exposure pathway duration and that the transport mechanisms are assumed to have reached equilibrium. This means that the levels will not decrease due to the exhaustion of the contaminant sources over the assumed exposure periods. The result of this assumption is a probable overestimation of exposure point concentrations because contaminant sources will not likely remain constant over time.

Finally, the assumption is made that human exposure remains constant over the lifetime of an individual. In actuality, lifestyle changes due to age and actual residence time will alter the projected exposure durations. Movement of individuals in and out of the potentially exposed community also affects exposure duration.

4.14.5.2 Toxicity Assessment

RfDs developed by the EPA are generally considered to have uncertainty spanning an order of magnitude or more. Consequently, total exposure HIs for the resident child and adult may be estimated high or low by an order of magnitude or more.

Low confidence by EPA in an RfD value, indicates high uncertainty in the accuracy of the toxicity value. High uncertainty indicates that the value may change in the future if additional toxicity data were to become available. Conversely, high confidence by the EPA in an RfD indicates low uncertainty in the accuracy of the toxicity value.

SFs developed by the EPA are generally conservative and represent the upper bound limit of the probability of a cancer response. Thus, the actual cancer risk due to exposure to the chemicals of concern is likely to be lower than the estimated risk.

A second area of uncertainty is those chemicals which were not included in the quantitative assessment because of lack of carcinogenic or noncarcinogenic toxicity values. Chemicals lacking RfD values include benzene and lead and those lacking SFs include 2-methylnapthalene, lead, and styrene. The total risk without considering these chemicals is underestimated.

4.14.6 Conclusions

A summary of future carcinogenic and noncarcinogenic risks was presented previously in Tables 4-119 through 4-122.

No current exposure pathways were identified at Site 9. Future exposure to chemicals of concern may occur if shallow aquifer domestic wells are installed.

Per MDNR guidance, a cancer risk exceeding 1×10^{-6} is an unacceptable human health risk. Total future cancer risk exceeding 1×10^{-6} was calculated for the on-site/recreational adult. Ingestion of groundwater exceeds the reference level but is the same order of magnitude. 1,4-dichlorobenzene contributes 50% of the risk for the ingestion pathway. The total cancer exposure risk to the recreational child equals 1×10^{-6}, indicating acceptable risk.

For noncarcinogenic effects, EPA guidance considers a HI greater than 1 to indicate potential for adverse noncarcinogenic health effects (EPA, 1989b). It has been demonstrated that the future HIs for the adult and child are below the reference level of 1, indicating a low potential for adverse noncarcinogenic effects.

Uncertainties in the risk assessment were evaluated in Section 4.14.5. The exposure frequency of 298 days/year for the on-site/recreational adult is a worst case scenario and overestimates the risk for this receptor.

No data is available regarding the deeper limestone aquifer. The potential for groundwater contaminants to migrate from the shallow aquifer to the deeper aquifer and contaminate on-site or off-site drinking wells was qualitatively assessed. The sandy clay observed at Site 9 is not considered an aquitard, consequently, the potential exists for contaminants to migrate vertically into the limestone aquifer if a vertical hydraulic gradient exists between the two aquifers. Class A and B carcinogens were detected in the shallow groundwater and could pose a health threat if exposure occurs.

4.15 ENVIRONMENTAL ASSESSMENT

This subsection provides a qualitative evaluation of risks to the natural environment posed by chemicals of concern in environmental media at sites 1 through 9. This information, in

conjunction with the human health evaluation and other information presented in the RI Report, will be used to assist in the determination of appropriate future action at the facility.

4.15.1 Endangered and Threatened Species

The Michigan Natural Features Inventory of the MDNR Wildlife Division identifies species of special concern that are known to be present in Alpena County. Both the federal and state status of these species are identified in Table 4-123. No survey has been conducted to determine whether any of these species inhabit the environment at, or adjacent to, the facility.

4.15.2 Ecological Setting

Five plant communities were identified at, or adjacent to, the Alpena CRTC:

- Deep Marsh Wetlands;
- Boreal Forest;
- Dry - Mesic Northern Forest;
- Dry Northern Forest;
- Old Fields; and
- Developed Areas.

These plant communities reflect the sandy acidic soils with rapid drainage that occur over much of the Alpena CRTC, disturbances related to operation of the CRTC, and possibly past fires. The three forest types grade into each other without a clear boundary between them. Figure 4-1 shows the approximate locations of the plant communities described below. The common plant species identified are listed by site in Table 4-124. The following wildlife was seen, or indications of their presence was identified on, or adjacent to, the facility:

Gull (*Larus* sp.)
American Crow (*Corvus brachyrhynchos*)
Red-eyed Virio (*Vireo olivaceus*)
Red-winged Black Bird (*Agelaius phoeniceus*)
Mallard (*Anas platyrhynchos*)
Wood Duck (*Aix sponsa*)
American Robin (*Turdus migratorius*)
Indigo Bunting (*Passerina cyanea*)
Eastern Pheobe (*Sayornis phoebe*)
Barn Swallow (*Hirundo rustica*)
Chipping Sparrow (*Spizell passerina*)
Pileated Woodpecker (*Dryocopus pileatus*)
Great Blue Heron (*Ardea herodias*)
Green-backed Heron (*Butorides striatus*)

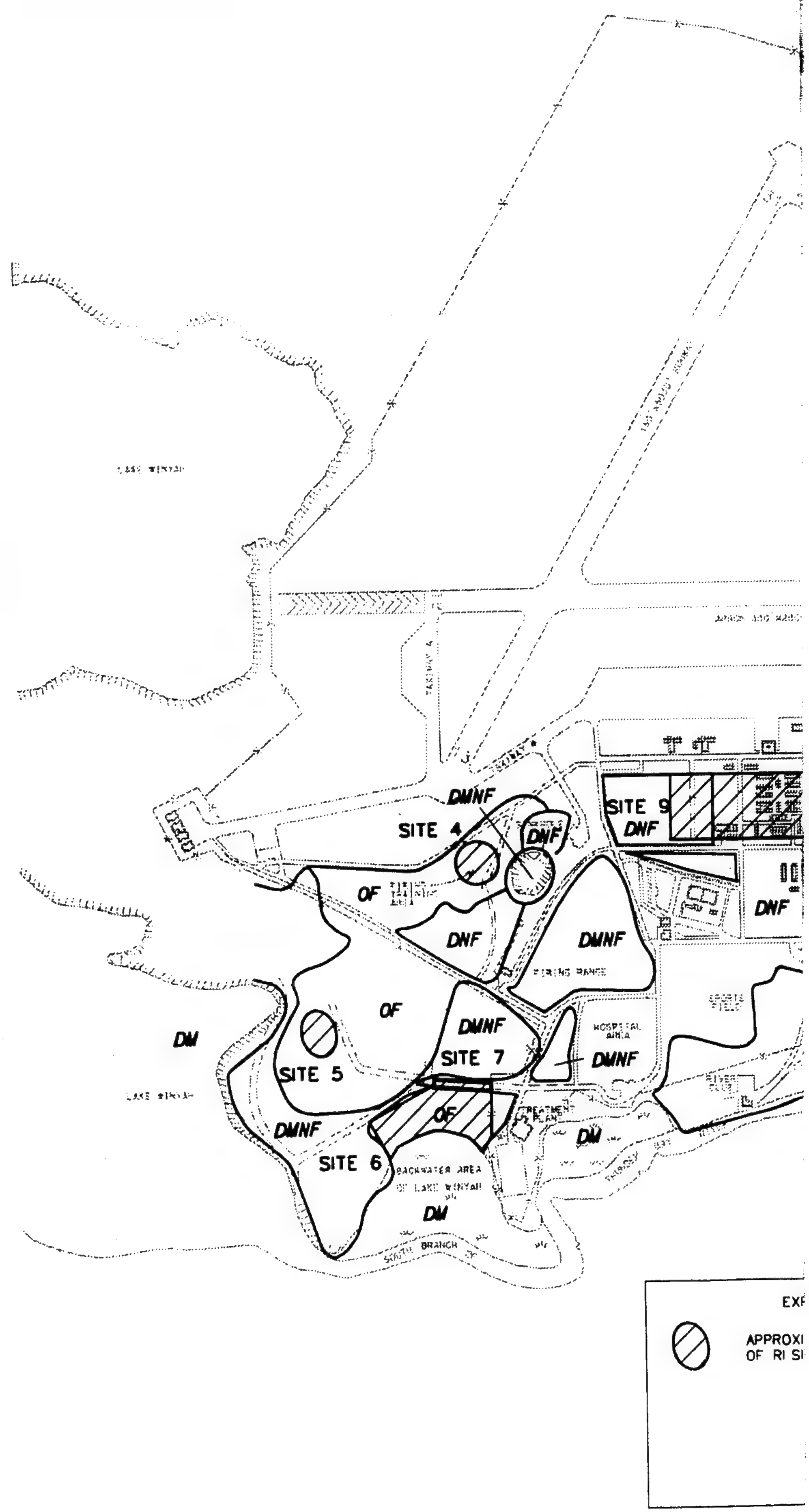
Table 4-123 Alpena County Natural Features Inventory
MIANG, Alpena CRTC, Alpena, Michigan

Type	Name	Common Name	Federal Status	State Status
P	Adlumia Fungosa	Climbing Fumitory		SC
P	Armoracia Aquatica	Lake Cress	C2	T
P	Botrychium Mesperium	Western Moonwort		T
P	Cacalia Plantaginea	Prairie Indian-Plantain		T
P	Calypso Bulbosa	Calypso or Fairy-Slipper		T
P	Camptosorus Rhizophyllus	Walking Fern		T
P	Carex Concinna	Beauty Sedge		SC
P	Carex Pallescens	Pale Sedge		SC
P	Carex Scirpoidea	Bulrush Sedge		T
P	Cirsium Pitcheri	Pitcher's Thistle	LT	T
P	Crataegus Douglasii	Douglas's Hawthorn		SC
P	Cryptogramma Stelleri	Slender Cliff-Brake		SC
P	Cypripedium Arietinum	Ram's Head Lady's-Slipper	3C	SC
P	Dryopteris Filix-Mas	Male Fern		T
A	Gavia Immer	Common Loon		T
A	Haliaeetus Leucocephalus	Bald Eagle	LELT	T
P	Iris Lacustris	Dwarf Lake Iris	LT	T
A	Lanius Ludovicianus Migrans	Loggerhead Shrike	C2	E
A	Notropis Anogenus	Pugnose Shiner		SC
A	Nycticorax Hycticorax	Black-Crowned Night-Heron		SC
A	Pandion Haliaetus	Osprey		T
A	Percina Copelandi	Channel Darter		T
P	Pinguicula Vulgaris	Butterwort		SC
P	Pterospora Andromedea	Pine-Drops		T
P	Salix Pellita	Satiny Willow		SC
A	Sistrurus Catenatus Catenatus	Massasauga	C2	SC
A	Sterna Caspia	Caspian Tern		T
A	Sterna Hirundo	Common Tern	C2	T
P	Tanacetum Huronense	Lake Huron Tansy		T
P	Trichostema Brachiatum	False Pennyroyal		T

Type Codes: A = Vertebrate Animal; P = Vascular Plant
Status Codes: E = Endangered; T = Threatened; SC = Special Concern (rare, may become E or T in future); C2 = E or T may be appropriate but more information is needed; 3C = Not currently being considered for listing; LT = Legally threatened; LELT = Dual status dependent upon location within its range: may be threatened or endangered depending upon the specific location

RI SITES

SITE 2 MOTOR POOL AREA
SITE 3 FORMER SITE OF COUNTY GARAGE
SITE 4 THIRD FIRE TRAINING AREA
SITE 5 SECOND FIRE TRAINING AREA
SITE 6 FORMER SOLID WASTE LANDFILL
SITE 7 FIRST FIRE TRAINING AREA
SITE 8 FORMER SITE OF HANGAR 9
SITE 9 RADAR TOWER SITE

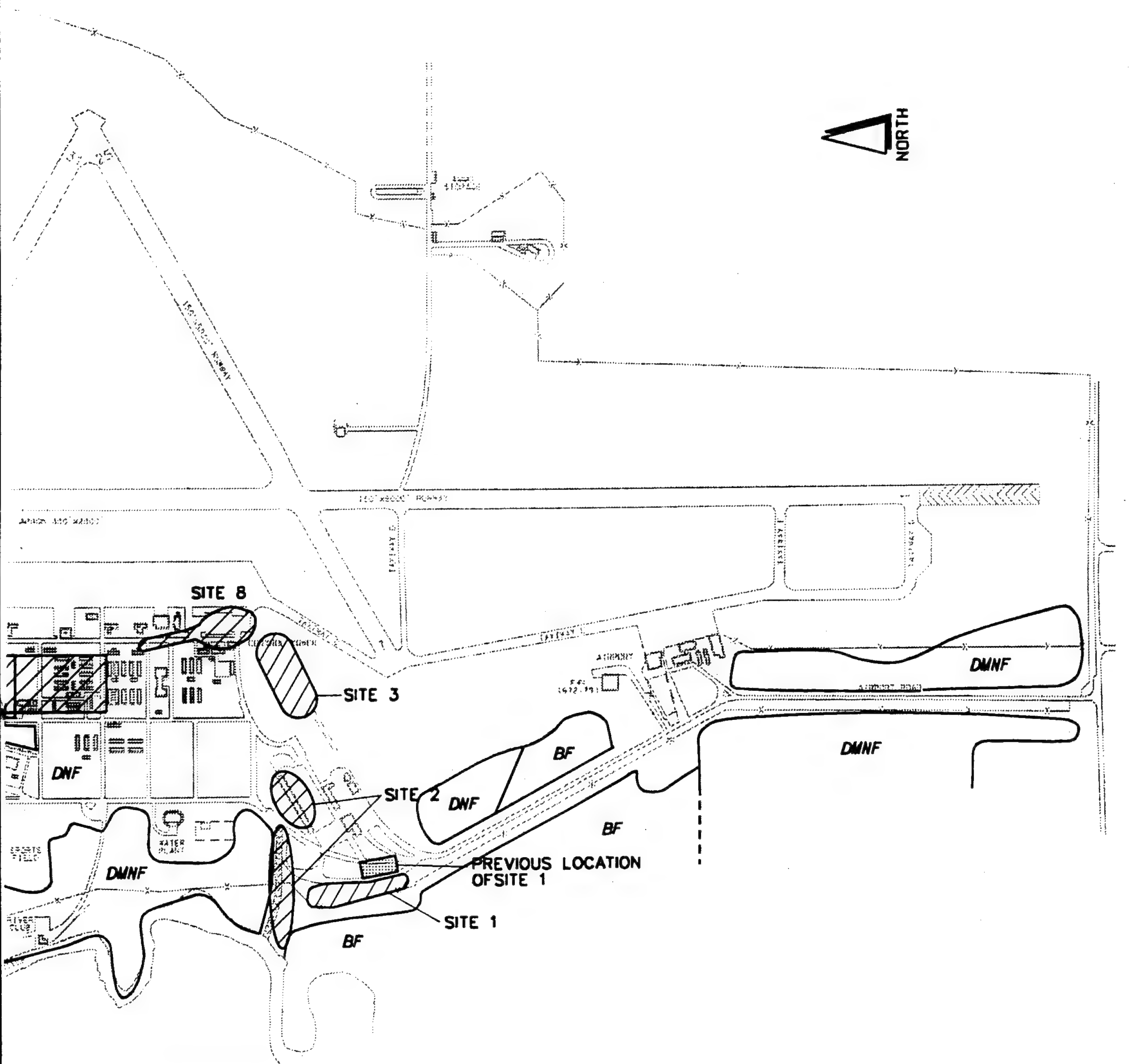


KEY

DM DEEP MARSH
BF BOREAL FOREST
OF OLD FIELD
DNF DRY NORTHERN FOREST
DMNF DRY-MESIC NORTHERN FOREST

NOTE: UNDESIGNATED AREAS ARE DEVELOPED AND/OR MOWED

931800RI.DGN



EXPLANATION

APPROXIMATE SITE BOUNDARY OF RI SITES

0 300 Meters

0 1000 Feet

Approximate Scale

The Earth Technology Corporation

PROJECT NO.

Alpena CRTC
Alpena, Michigan

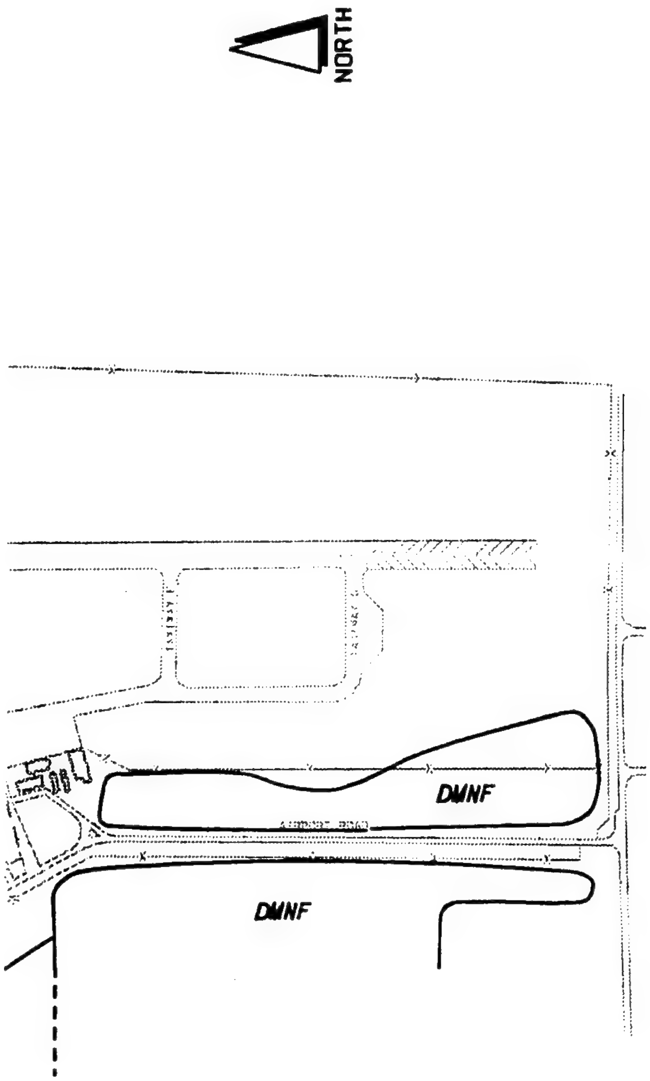
DRAFT

APPROXIMATE LOCATIONS O
PLANT COMMUNITIES

7-94

FIGURE

(2)



The Earth Technology Corporation

PROJECT NO. 928901

Alpena CRTC
Alpena, Michigan

DRAFT

APPROXIMATE LOCATIONS OF PLANT COMMUNITIES

7-94

FIGURE 4-1

(3)

Table 4-124
Common Plant Species at Sites and the Sinkhole
Alpena CRTC, Alpena, Michigan

Name		Site									
Common Name	Scientific Name	1	2	2 (ditch)	3	4	5	6 & 7	8	9	Sinkhole
Alfalfa	Medicago sativa		X					X			
Ash	Fraxinus sp.							X			
Balsam Fir	Abies balsamea	X								X	
Balsam Poplar	Populus balsamifera			X			X	X			
Black Berry	Rubus sp.						X				
Black Oak	Quercus velutina			X	X			X		X	X
Bladder Campion	Silene cucubalus					X	X				
Blueberry	Vaccinium sp.	X								X	
Bracken Fern	Pteridium aquilinum	X		X				X		X	X
Bull Thistle	Cirsium vulgare										
Bunchberry	Cornus canadensis	X									
Buttercup	Ranunculus sp.						X				
Canada Thistle	Cirsuim virginianum										X
Cattails	Typha sp.							X			
Chickweed	Stellaria pubera				X						
Common Burdock	Arctium minus										X
Common Milkweed	Asclepias syriaca	X		X			X	X			X
Common Ragweed	Ambrosia artemisiifolia	X						X			
Dandelion	Taraxacum officinale		X		X		X	X			
Dogbane	Apocynum sp.							X			
English Plantain	Plantago lanceolata	X	X			X					
Equisetum	Equisetum sp.	X						X			
Field Hawkweed	Hieracium pratense	X									X
Fleabane	Erigeron strigosus	X									X
Goat's Beard	Tragopoton pratensis			X		X	X				
Goldenrod	Salidago sp.			X							
Hoary Alyssum	Berteroa incana						X	X			
Jack Pine	Pinus banksiana	X			X					X	
Juniper	Juniperus horizontalis			X							
Kinickinick	Arctostaphylos uva-ursi									X	
Leafy Spurge	Euphorbia esula						X	X			
Lily of the Valley	Maianthemum	X								X	X
Moss	Fontinalis sp.										X
Mullein	Verbascum thapsus			X			X	X			
Northern White Cedar	Thuja occidentalis								X		
Orange Hawkweed	Hieracium aurantiacum	X								X	X
Ox-eye Daisy	Chrysanthemum leucanthemum	X	X	X		X	X	X			
Poison Ivy	Toxicodendron radicans									X	
Potamageton	Potamageton sp.										X
Raspberry	Rubus sp.			X				X			X
Red Maple	Acer rubrum	X									X
Red Pine	Pinus resinosa			X							
Rushes	Scirpus sp.							X			
Sand Bar Willow	Salix exigua										X
Sasparilla	Aralia nudicaulis										X
Sedges	Cyperaceae			X				X			X
Shadbush	Amelanchier sp.									X	X
Sheep Laurel	Kalmia angustifolia	X		X							
Shrubby Cinquefoil	Potentilla fruiticosa								X		
Speckled Alder	Alnus rugosa							X			X
Spike Rush	Eleocharis sp.										X
Spotted Knapweed	Centaurea maculosa		X		X	X	X	X			
Sweet Cicely	Osmorhiza claytoni										X
Sweet Fern	Comptonia peregrina			X			X	X			
Trembling Aspen	Populus tremuloides	X								X	X
Violet	Viola sp.	X									
Water Cress	Nasturtium officinale										X
White Birch	Betula papyrifera	X									X
White Campion	Lychnis alba										
White Clover	Trifolium repens	X				X	X				
White Pine	Pinus strobus	X									X
White Spruce	Picea alba		X								
Wild Grape	Vitus riparia										X
Willow shrubs	Salix sp.				X						X
Wintergreen	Gaultheria procumbens	X								X	
Yarrow	Achillea millefolium						X				
Yellow Clover	Trifolium sp.						X				
Yellow Water Lily	Nuphar variegatum										

Northern Flicker (*Colaptes auratus*)
Eastern Wood Pee Wee (*Contopus virens*)
Eastern Bluebird (*Sialia sialis*)
Muskrat (*Ondatra zibethica*)
Eastern Chipmunk (*Tamias striatus*)
Red Squirrel (*Tamiasciurus hudsonicus*)
Eastern Gray Squirrel (*Scirius carolineusis*)
White-tailed Deer (*Odocoileus virginianus*)
Raccoon (*Procyon lotor*)
Northern Leopard Frog (*Rana pipens*)
Green Frog (*Rana clamitans melanota*)
Garter Snake (*Thamnophis* sp.)
Northern Water Snake (*Nerodia sipedon*)
Wood Turtle (tentative identification based on eggs only, C*lemmys insculpta*)

<u>Deep Marsh</u>

Deep marshes occur in the backwater of the Thunder Bay River. Deep marsh plant communities have standing water depths of between 6 in and 3 or more ft during most of the growing season and are dominated by herbaceous emergent, floating, floating-leaves, and submergent plants (Reed and Eggers, 1987). Plants in the deep marsh at the Alpena CRTC include yellow water lily, cattails, sedges, rushes and pond weeds.

<u>Boreal Forest</u>

Boreal forests occur in the west side of the Alpena CRTC to the west of the entry road and Site 1. The boreal forest occurs on upland sites in glacial lake plains with sandy and moderately acid to neutral soils (Michigan Natural Features Inventory, 1989). Dominant plants are balsam fir, white spruce, northern white cedar, and white birch.

<u>Dry - Mesic Northern Forest</u>

The dry - mesic northern forest community occurs between the dry northern forest and the Thunder Bay River. This community occurs on sandy glacial outwash and sandy lake plains with acidic soils (Michigan Natural Features Inventory, 1989). Portions of the developed part of the Alpena CRTC were formerly dry - mesic northern forest. Dominant plants found on the site in this plant community at the Alpena CRTC are white pine, red pine, black oak, trembling aspen, and red maple. The understory includes blueberry, shadbush, bracken fern, sheep laurel, wintergreen, bunchberry, and kinickinick (bearberry).

<u>Dry Northern Forest</u>

A dry northern forest community occurs on much of the Alpena CRTC area west of the runway. This is a pine forest occurring on dry sites, principally sandy glacial outwash and sandy glacial lake plains with dry sandy, acidic soils (Michigan Natural Features Inventory, 1989). The dominant plants in this community at the Alpena CRTC are jack pine and black oak with an understory dominated by blueberry and bracken fern. Much of the developed part of the Alpena CRTC was probably originally dry northern forest. In many areas the understory has been removed and is now maintained as a lawn, while the larger trees remain.

Old Fields

Much of the Alpena CRTC has been cleared, and some of the sites are in these clearings. The clearings have been disturbed to various degrees by activities at the Alpena CRTC. These areas are dominated by weed species such as spotted knapweed, hoary alyssum, ox-eye daisy, bladder campion, alfalfa, chickweed, leafy spurge, common milkweed, blackberry, and other opportunistic species.

Developed Areas

Much of the site is developed and is covered by parking areas, runways, clear zones for the runways, equipment storage areas, and buildings. These areas either have very little vegetation or are maintained as lawns. Some larger trees such as jack pine, white pine, and black oak remain in some of the mowed areas, especially near the dormitories area.

There are numerous aquatic habitats adjacent to the facility, particularly those associated with the Thunder Bay River. The sinkhole is the only surface water body on the facility typically present year-round. Surface runoff to the sinkhole is minimal due to the high infiltration rate of the sandy soil across the facility. The sinkhole, which is an isolated water body, receives subsurface drainage from a large portion of the facility. There are numerous seeps along the water line which feed the sinkhole. Wildlife has been observed using the sinkhole as a water source. Fish have been observed within the sinkhole.

The majority of the RI sites at the facility are located totally or partially in Grayling Sand. Grayling sand, found at Sites 2, 3, 4, 8, and 9, is characterized as having very rapid drainage. Rubicon sand, also found at Site 2, has fair to good drainage. The remaining soils are all listed as hydric soils by the U.S. Department of Agriculture, Soil Conservation Service. Lupton Muck is a *typic borosaprist* and Rifle Peat is a *typic borohemist*; both are classified as very poorly drained organic soils (U.S. Department of Agriculture, 1987). Both of these hydric soils typically support wetlands as defined under Section 404 of the Clean Water Act. Thus, Sites 5, 6, and 7 may be located in wetlands, however, a jurisdictional delineation and determination by the U.S. Army Corps of Engineers has not been made for the facility. There are also areas of Saugutuck Sand, Houghton Muck, and Granby Sand on the facility. These three soil types are also listed as hydric soils and may support wetlands, especially in areas that have not been drained.

4.15.3 Exposure Assessment

Exposure assessments were developed for each site within the Alpena CRTC for which chemicals of concern were identified. Exposure pathways were identified for both current and future land-use scenarios. Aquatic and terrestrial organisms may be exposed to chemicals in environmental media via several pathways. Aquatic organisms may be exposed via direct contact with, and ingestion of, surface water and sediment, as well as consumption of contaminated aquatic plants and prey species. Terrestrial organisms may be exposed to chemicals via ingestion of and/or dermal contact with surface soils, as well as through the food chain.

Groundwater, surface water, soil, and sediment were considered as potential release sources for all nine sites included in the RI. Potential transport media considered include air, surface water, groundwater, soils, and sediments. Potential release mechanisms included volatilization of organic compounds, fugitive dust generation, site leaching, tracking (dispersal of contaminants from contaminated soils carried on the feet of animals and humans), and groundwater seepage to surface waters. Potential receptors include aquatic organisms, terrestrial wildlife, birds, and plants. Domestic animals have not been identified as potential receptors because there is no permanent housing on the facility. The only area where domestic animals may be present is the family campground. Although stray domestic animals may be present at a site, such occurrences are likely to be single incidence and the probability of their exposure to chemicals of concern is small or none.

Subsurface soils, soils found at depths greater than 0.9 m (3 ft), are not considered to pose a potential threat to animal or plant life in this ecological risk assessment. A potential release to aquatic organisms from contaminated subsurface soils on site would occur from contaminants migrating to the groundwater and moving with the groundwater to a surface water release. Typically, 99 percent of a plant's root system is found in the top three feet of soil; therefore, contaminated soils at depths greater than this are not considered a potential threat to plants. The definition of surface soil, as used in this ecological risk assessment, includes those soils found at depths from 0 to 0.9 m (0 to 3 ft) below ground surface.

The chemicals of concern are identified for each medium at each site. Inorganic chemicals of concern for soil, were identified as those metals present in the soil in concentrations above the Michigan Act 307 Type A cleanup criteria (as presented in Section 4.1.1). The soil data for organic compounds was compared to Act 307 Type B cleanup criteria. This value is considered conservative because it is based on protecting human receptors rather than ecological receptors. Available TCLP leachate data were used as an indication of the concentration available for plant uptake. The chemicals of concern identified for water are those chemicals whose concentration exceeds the Michigan Act 307 Type B GSI value. These values are listed in Table 4-1. Filtered data were used for groundwater monitoring well samples and both unfiltered and filtered were used for surface water data.

4.15.3.1 Site 1 POL Storage Area

Characterization of the Exposure Setting

Site 1 occupies an area of approximately 9,660 square meter(s) (m^2) (103,700 square feet (ft^2) within a fenced area inside the Alpena CRTC (see Figure 1-2). The site was the former POL storage area for the facility. The site is predominately gravel-covered with a gravel road. The road runs north-south approximately two-thirds the length of the site. The ANG currently uses the area to park large vehicles. A large storage building is also present on the north end of the site. The dominant plants are jack pine, white pine, and grasses. The jack pines occur in the northern part of this site, and the white pine occur in a row along the east side. The understory is limited by mowing, but includes blueberry, sheep laurel, lily of the valley, and bracken fern. Other species present are listed in Table 4-131. The deer fencing, which includes barbed wire along the top, encircles the perimeter of the adjacent land. Areas adjacent to the site, encompassed within the fenced area, are grass covered. To the west, toward Thunder Bay River, is a boreal forest community. The south branch of the Thunder

Bay River is located approximately 46 m (150 ft) to the west. North of the site is a dry-mesic northern forest community. Depth to groundwater is approximately 0.6 to 1.2 m (2 to 4 ft) bgs. The direction of groundwater flow within the perched aquifer is northwest toward the Thunder Bay River.

Identification of Chemicals of Potential Concern

Chlorobenzene, ethylbenzene, and styrene were all detected in soils within the root-zone depth of 0.6 to 0.9 m (2 to 3 ft) at concentrations above Act 307 Type B cleanup criteria. Copper, chromium, lead, nickel, cadmium, 1,2-dichlorobenzene, 1,4-dichlorobenzene, ethylbenzene, mercury, and zinc were detected within the shallow aquifer at concentrations above Act 307 GSI values.

Identification of Exposure Pathways/Receptors

Air: The potential release mechanism and source for the transport medium air is volatilization of chlorobenzene, ethylbenzene, and styrene within site soils. The potential receptors would be terrestrial wildlife, birds, and the plant community, whose primary exposure route would be inhalation. Volatile organic contaminants found in the soils of Site 1 may migrate through the soil pores of the vadose zone to the ground surface, making this pathway complete.

Surface Water: The potential release sources and mechanisms for the transport medium surface water are surface runoff from contaminated surface soils and groundwater seepage of contaminated groundwater. Potential receptors are aquatic organisms, terrestrial wildlife, and birds. The chemicals of concern in the site soils are not located on the surface therefore, surface runoff is not a release mechanism. RI groundwater flow data indicate that groundwater, in which chemicals of concern were detected, is migrating toward Thunder Bay River. No surface water sampling of Thunder Bay River was conducted. One groundwater monitoring well, well P1MW12, located approximately 30.5 m (100 ft) from Thunder Bay River and considered representative of the GSI, was sampled. Concentrations of chromium (50.1 ppb), lead (12.7 ppb), and zinc (89.2 ppb), all found in Well P1MW12 are above Act 307 GSI criteria. Based on groundwater modeling data, it is estimated the maximum concentration of copper (0.02 ppb), cadmium (0.009 ppb), chromium (0.02 ppb), mercury (0.001 ppb), nickel (0.17 ppb), 1,4-dichlorobenzene (0.03 ppb), 1,2-dichlorobenzene (2.01 ppb), and ethylbenzene (0.1 ppb) discharged to Lake Winyah will be below Act 307 GSI criteria. These data indicate that the groundwater exposure pathway to surface water is complete.

Groundwater: The potential release mechanism and source for the transport medium groundwater is leaching of contaminated soils. The only potential receptors are plants whose primary exposure route would be their root system. Groundwater at Site 1 is located 0.6 to 1.2 m (2 to 4 ft) bgs. There is a potential for plant roots to extend to the groundwater and thus be exposed to chromium, lead, and zinc which were detected at concentrations above Act 307 GSI criteria. The exposure pathway for groundwater is complete and will remain so in the future unless groundwater levels should fall.

Soils: Potential release mechanisms for soil are leaching into the groundwater, tracking by mammals, and fugitive dust generation. Potential receptors are terrestrial wildlife, birds, and plants. The primary exposure routes are oral consumption, dermal contact, and uptake by

plant root systems. The deer fencing is an effective barrier to wildlife or domestic animals coming in contact with vegetation on-site. Also, because the majority of the site is gravel-covered, there is little to attract primary consumers. Lack of primary consumers would discourage the presence of secondary consumers on-site. Predators that may have a potential for exposure would be those that feed on burrowing animals which have been exposed to chemicals of concern through contact with contaminated soils at the site.

The current pathway for exposure to chlorobenzene, ethylbenzene, and styrene from soils at Site 1 is complete for burrowing animals and plants. Burrowing animals living in contaminated subsurface soils on-site may be exposed to chlorobenzene, ethylbenzene, and styrene. Only those animals that burrow to a depth of two ft or greater would be at risk of exposure. Plants whose root systems extend to a depth of two ft or more would also be exposed to chemicals of concern. Presently grass is the predominant vegetation at Site 1. Soil contaminants may occur in plant parts used as food by certain animals. The current exposure potential for plants to chemicals of concern is low because the majority of plant roots, particularly grass, are located in the first 0.6 m (2 ft) of soil. The chemicals of concern at Site 1 were found at depths 0.6 m (2 ft) and greater. The exposure potential for plants could increase should the current top 0.3 m (1 ft) of soil be removed in the future. Plant root systems might then extend into the zone of contaminated soil. Should contaminated soils be exposed at ground surface in the future, all potential receptors present at the site may be exposed to chlorobenzene, ethylbenzene, and styrene.

Sediments: The potential release mechanisms for sediment are site leaching and tracking. The potential sources are contaminated groundwater and surface soil. Aquatic organisms, terrestrial wildlife, birds, and plants are the potential receptors. The surface soil pathway is not complete because the soil contaminants are not located on the ground surface. The groundwater pathway is complete based on monitoring well P1MW12 data.

Ecological Hazard Assessment

The current exposure pathway and its associated receptors and chemicals of concern for Site 1 are summarized in Table 4-125. The potential impacts upon ecological receptors from exposure to ethylbenzene, chromium, lead, and zinc are discussed below. No data were available for chlorobenzene or styrene, however, because they are similar to ethylbenzene the ecological impacts are assumed to be similar.

Chromium: Chromium hazards to sensitive aquatic species have been documented at 10.0 ppb of hexavalent chromium. Records of acute toxicities to representative species of aquatic life have made it clear that hexavalent chromium is more toxic to freshwater biota in comparatively soft and acidic waters, that younger life stages are more sensitive than older organisms, and that 96 hours is insufficient to attain stable mortality patterns. (U.S. Department of the Interior, January 1986). A freshwater aquatic toxicity value was figured for hexavalent chromium. The lowest acute effective concentration, based on a one-hour average, is 1.6×10^{1} $\mu g/\ell$ (IRIS, 1993). The lowest chronic effective concentration, based on a four-day average, is 1.1×10^{1} $\mu g/\ell$ (IRIS, 1993). A toxicity value of 5 mg/kg may produce death in mice (CHR 85). The soil to plant uptake value for hexavalent chromium is 7.50×10^{-3} (MEPAS, 1989).

Table 4-125 Current Exposure Pathways for Site 1
MIANG, Alpena CRTC, Alpena, Michigan

	Receptors				
Pathway	Terrestrial Wildlife	Birds	Plants	Aquatic Organisms	Chemicals of Concern
Air	✓	✓	✓		Chlorobenzene, ethylbenzene, styrene
Surface Water	✓	✓		✓	Chromium, lead, zinc
Groundwater			✓		Chromium, lead, zinc
Soils	✓		✓		Chlorobenzene, ethylbenzene, styrene
Sediments	✓	✓	✓	✓	Chromium, lead, zinc

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Ethylbenzene: Research shows that volatilization of ethylbenzene occurs in soil and most likely will decrease its concentration. Because ethylbenzene has a moderately high vapor pressure it will evaporate fairly quickly in dry soil. Toxicity levels have been determined for several animals. For rats several toxicity values, which are 3,500 mg/kg (RTECS, March 1993), 136 mg/kg per day (IRIS, March 1993), and 408 mg/kg per day (IRIS, March 1993), have been found for oral exposure of ethyl benzene. Inhalation toxicity values for mice, guinea pigs, rats, and rabbits are 4,000 ppm per 4 hours (RTECS, March 1993), 50,000 milligrams per cubic meter (mg/m^3) per 2 hours (RTECS, March 1993), 10,000 ppm (RTECS), 100 ppm (IRIS, March 1993), and 100 ppm (IRIS, March 1993), respectively. The soil to plant uptake value is 1.5×10^1 (MEPAS, 1989).

Lead: Lead is generally considered a highly toxic contaminant because it is not an essential nutrient to either plants or animals. Lead bioaccumulates in animal tissues, but has a low potential for biomagnification in the food chain. The solubility of lead is dependent on water hardness, and is considered 20 to 100 times more toxic in soft water. In aquatic environments, most lead is found in bottom sediments and is therefore a concern more in benthic organisms than in planktonic or pelagic forms. Toxicity of lead in water is dependent on pH, organic materials, and the presence/absence of other metals. The primary mechanism of acute toxicity of lead to freshwater organisms is unknown. Invertebrate species appear more sensitive than vertebrate species. Lead inhibits plant growth and reduces photosynthesis, mitosis, and water absorption.

Zinc: The toxicity values for rats through oral exposure ranges from 0.1 to 1 percent for zinc in their diet (Clayton and Clayton, 1981). At 0.5 percent rats capacity to reproduce may be reduced. At 1 percent the effects may be inhibited growth, severe anemia, and death. The soil to plant uptake value is 4.00×10^{-1} (MEPAS, 1989). The toxicity value for plants may be affected by pH in the soil. One study found that a pH of 5.5 may reduce wheat yields by 20 percent at a toxicity value of 20 eq/mil added as $ZnSO_4$ (Leeper, 1978). A toxicity value of 0.9 meg Zn/100 g soil in soil with a pH value of 6.1 caused plant damage to both swiss chard and spinach.

4.15.3.2 Site 2 Motor Pool Area

Characterization of the Exposure Setting

Site 2, the Motor Pool Area, occupies an area of approximately 21,440 m^2 (230,100 ft^2). A portion of Site 2 includes a drainage ditch in which contaminants have been detected in the soil. A source removal action with confirmatory sampling for residual risk is currently planned for the drainage ditch soils and therefore soils for this area will not be addressed in this section. The remaining portion of Site 2 has a fence that surrounds the site and limits access to the area (see Figure 1-5). There are three structures on-site: one building and two long, covered parking structures used to store facility heavy equipment and vehicles. The site is primarily asphalt covered with a very small lawn that supports grasses and some weedy species, and a medium-sized white spruce tree near Building 7. Other species present are listed in Table 4-131. There is a lawn with several black oak trees to the east, a lawn with several white and red pine trees to the south, a lawn and a road to the west, and a road to the north of Site 2. North, east, and south, beyond the immediate vicinity of the site, are

developed areas consisting of buildings and roads. To the west is primarily undeveloped land consisting of grass-covered areas or forest. Shallow groundwater is present at 1.8 to 2.4 m (6 to 8 ft) bgs and flows north to northwest toward the sinkhole.

Identification of Chemicals of Potential Concern

Lead was found at a concentration above Act 307 Type A cleanup criteria in one surface soil sample. It was not identified as a chemical of potential concern because the sampling location (SB6) was south of the site, well outside the boundary of Site 2. No chemicals of concern were identified in any other borings. Zinc, copper, and silver were detected in the groundwater at concentrations which exceeded the Act 307 Type B GSI values.

Identification of Exposure Pathways/Receptors

Air: The potential release mechanism and source for the transport medium air is volatilization of contaminated soils. The potential receptors would be terrestrial wildlife, birds, and the plant community whose primary exposure route would be inhalation. No volatile or semivolatile compounds were detected in soils above Act 307 Type B cleanup criteria; therefore, air is not a complete pathway.

Surface Water: The potential release sources and mechanisms for the transport medium surface water are surface runoff from contaminated surface soils and groundwater seepage of contaminated groundwater. Potential receptors are aquatic organisms, terrestrial wildlife, and birds. No chemicals of concern were detected in surface soil; therefore, this is not a release source. RI groundwater flow data indicate that groundwater, in which chemicals of concern were detected, is migrating toward the sinkhole. Although this exposure pathway is not currently complete, terrestrial wildlife, birds, and aquatic organisms could become future potential receptors through oral or dermal contact should contaminated groundwater discharge to the sinkhole. Based on groundwater modeling data, the estimated maximum concentration of copper (0.026 ppb), zinc (9.1 ppb), and silver (0.002 ppb) discharged to the sinkhole will be below Act 307 GSI criteria. The surface water exposure pathway may become complete in the future, but the concentrations of chemicals of concern released to the sinkhole are estimated to be below levels which will adversely affect environmental receptors.

Groundwater: The potential release mechanism and source for the transport medium groundwater is leaching of contaminated soils. The only potential receptors are plants whose primary exposure route would be root uptake. However, the groundwater at Site 2 is located at a depth greater than plant roots are likely to extend. This exposure pathway is currently, and most likely will remain, incomplete.

Soils: Potential release mechanisms for soil are leaching into the groundwater, tracking by mammals, and fugitive dust generation. Potential receptors are terrestrial wildlife, birds, and plants. The primary exposure routes are oral consumption, dermal contact, and uptake by plant root systems. Soils are not a current or future potential pathway because no chemicals of concern were detected in the site soils.

Sediments: The potential release mechanisms for sediment are site leaching and tracking. The potential sources are contaminated groundwater and surface soil. Aquatic organisms,

terrestrial wildlife, birds, and plants are the potential receptors. Because no surface soil contamination was found, this pathway is, and will remain, incomplete. Groundwater from beneath the site will not pose a contamination potential for sediment based on the groundwater modeling data.

Ecological Hazard Assessment

None of the exposure pathways at Site 2 are presently complete. It is anticipated that should an exposure pathway become complete, the concentrations of chemicals released will not adversely affect environmental receptors.

4.15.3.3 Site 3 Former Site of County Garage

Characterization of the Exposure Setting

Site 3 is the site of the former county garage. The site extends over approximately 15,840 m^2 (170,000 ft^2), which is predominately grass covered with the exception of the old concrete foundation of the garage and areas where gravel roads dissect the site (see Figure 1-6). The lawn is dominated by grasses, and weed species such as chickweed, knapweed, and dandelions. Table 4-131 lists the common species at this site. Site 3 is surrounded by developed areas, including a road to the east, a mowed area with some jack pine, black oak trees to the east, a mowed clear zone to the south, and a mowed area with some black oak and jack pine to the west. North of the site is the developed area of the facility consisting of buildings and roads. South of the site borders the taxiways and runways are to the east. Groundwater at Site 3 occurs within the shallow aquifer at depths ranging from approximately 3 to 5.8 m (10 to 19 ft) bgs. Groundwater flow direction is north, toward the sinkhole.

Identification of Chemicals of Potential Concern

Concentrations of benzo (k) fluoranthene, chrysene, benzo (a) anthracene, and benzo (b) fluoranthene were detected in soil at a depth within the plant root zone. These same chemicals plus benzo (a) pyrene, dibenzofuran, and ideno (1,2,3-c,d) pyrene were all detected in subsurface soils. All of these chemicals were detected at levels above Act 307 Type B cleanup criteria for soils. Copper, cadmium, chromium, and lead were the only chemicals detected in the groundwater at concentrations above the Act 307 GSI values. Diethyl phthalate, for which no allowable limit has been established, was also detected in the groundwater.

Identification of Exposure Pathways/Receptors

Air: The potential release mechanism and source for the transport medium air is volatilization of chemicals of concern within soils. The potential receptors would be terrestrial wildlife, birds, and the plant community, whose primary exposure route would be inhalation. No volatile or semi-volatile compounds were detected in soils above Act 307 Type B cleanup criteria; therefore, air is not a complete pathway.

Surface Water: The potential release sources and mechanisms for the transport medium surface water are surface runoff from contaminated surface soils and groundwater seepage of contaminated groundwater. Potential receptors are aquatic organisms, terrestrial wildlife, and birds. Although surface runoff could be a transport mechanism for contaminated surface soil, there is no surface water body located close enough to the site for surface runoff of contaminated soils to enter. RI groundwater flow data indicate that groundwater, in which chemicals of concern were detected, is migrating toward the sinkhole. Although there are no current complete exposure pathways, terrestrial wildlife, birds, and aquatic organisms could become future potential receptors through oral or dermal contact should contaminated groundwater discharge to the sinkhole. Based on groundwater modeling data the estimated maximum concentration of cadmium (0.004 ppb), chromium (0.02 ppb), copper (0.02 ppb), and lead (0.01 ppb) discharged to the sinkhole will be below Act 307 GSI criteria. No GSI value has been determined for the analyte diethyl phthalate, which has an estimated maximum concentration of 0.09 ppb.

Groundwater: The potential release mechanism and source for the transport medium groundwater is leaching of contaminated soils. The only potential receptors are plants, whose primary exposure route would be by root uptake. However, groundwater at Site 3 is located at a depth greater than plant roots are likely to extend. This exposure pathway is currently, and most likely will remain, incomplete.

Soils: Potential soil release mechanisms are leaching into groundwater, tracking by animals and people, and fugitive dust generation. Potential receptors are terrestrial wildlife, birds, and plants. The primary exposure routes are oral consumption, dermal contact, and uptake by plant root systems. The current pathway for exposure to chemicals of concern within the soils at Site 3 is complete for all receptors because benzo (k) fluoranthene, chrysene, benzo (a) anthracene, benzo(a)pyrene, bibenzofuran, ideno(1,2,3-c,d)pyrene, and benzo (b) fluoranthene were detected in site soils.

Sediments: The potential release mechanisms for sediment are site leaching and tracking. The potential sources are contaminated groundwater and surface soil. Aquatic organisms, terrestrial wildlife, birds, and plants are the potential receptors. The sediment exposure pathway is currently incomplete, because the groundwater maximum contaminant concentrations are estimated to be below Act 307 GSI criteria at the sinkhole, and the distance is too great for the transport of surface soil contaminants to sinkhole sediments. Site 3 groundwater may become an exposure pathway for the release of diethyl phthalate to the sinkhole in the future.

Ecological Hazard Assessment

The current and future exposure pathways and their associated receptors and chemicals of concern for Site 3 are summarized in Table 4-126. The potential impacts upon ecological receptors from exposure to chemicals of concern are discussed below. Specific data were not available for benzo(k)fluoranthene, chyrsene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, dibenzofuran, and ideno(1,2,3-c,d)pyrene: these are generally discussed below as PAHs.

Diethyl phthalate: Research conducted on the oral exposure of rats to diethyl phthalate found that reproductive performance after oral administration of 0.25, 1.25, and 2.5 percent for 18

Table 4-126 Current Exposure Pathways for Site 3
MIANG, Alpena CRTC, Alpena, Michigan

	Receptors				
Pathway	Terrestrial Wildlife	Birds	Plants	Aquatic Organisms	Chemicals of Concern
Air					
Surface Water					
Groundwater					
Soils	✓	✓	✓		Benzo(k)fluoranthene, chryzene, benzo(a)anthrancene, benzo(b)fluoranthene, benzo(a)pyrene, dibenzofuran, ideno(1,2,3-c,d)pyrene
Sediments					

Future Potential Exposure Pathways for Site 3
MIANG, Alpena CRTC, Alpena, Michigan

	Receptors				
Pathway	Terrestrial Wildlife	Birds	Plants	Aquatic Organisms	Chemicals of Concern
Air					
Surface Water	✓	✓		✓	Diethyl phthalate
Groundwater					
Soils					
Sediments	✓	✓	✓	✓	Diethyl phthalate

weeks did not appear to have any adverse affects. Second-generation breeding pairs exhibited increased right epididymis and prostate weights in males and decreased pituitary weight in females after exposure to 2.5 percent diethyl phthalate. Another study found no changes in behavior or other clinical signs of toxicity in rats after prolonged oral exposure. A significant decrease in weight gain was noted throughout the study in both sexes given 5 percent diethyl phthalate (15 to 25 percent decreases) and in females (5 to 8 percent decrease) fed 1 percent diethyl phthalate (IRIS, 1993).

Acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 940 and 3 $\mu g/\ell L$, respectively, and would occur at lower concentrations among more sensitive species that were not tested (EPA, 1986).

PAHs: Inter and intraspecies responses to PAHs are quite variable, and are significantly modified by other chemicals including other PAHs. PAHs cause embryotoxicity when applied to the surface of mallard eggs. There is a scarcity of data on PAH background. PAHs show little tendency for bioaccumulation, despite their high lipid solubility. Amphibians are quite resistant to PAH carcinogenesis when compared to mammals. There are sufficient data to confirm animal carcinogenicity for chrysene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3-c,d)pyrene (IRIS, March 1993). Terrestrial plants can absorb PAHs from soils through their roots, and translocate them to other parts of the plant. Uptake rates are governed by PAH concentration, solubility, soil type, and PAH physiochemical state. Low molecular weight PAHs absorbed more readily than those with higher molecular weight. PAH induced phytotoxic effects are rare and not well documented. PAHs persist in the soil for a long time and are not taken up by plants to an appreciable extent. Soil to plant uptakes are 5.61×10^{-3} for benzo(a)anthracene, 3.04×10^{-3} for benzo(a)pyrene, 3.04×10^{-3} for benzo(b)fluoranthene, 3.04×10^{-3} for benzo(k)fluoranthene, and 5.54×10^{-3} for chrysene (MEPAS, 1989).

4.15.3.4 Site 4 Third Fire Training Area

Characterization of the Exposure Setting

Site 4 is the third fire training area which occupies an area of approximately 5,730 m^2 (61,500 ft^2) (see Figure 1-7). The site consists of a concrete pad and an underground pipeline located in an old field community dominated by weedy species such as spotted knappweed, english plaintain, ox-eye daisy, goat's beard, white clover, and bladder campion. Table 4-131 lists the common species of this area. The soils at Site 4 will be remediated under a source removal action and are not considered in this risk assessment. Land immediately surrounding the site is primarily grass-covered fields. To the east of Site 4 are runways, taxiways, and associated clear zones; to the north is a large old field, to the west is a northern dry forest dominated by jack pine and black oak, and the sinkhole is to the south. The sinkhole supports a dry-mesic northern forest. Common species in and near the sinkhole are black oak, white birch, shadbush, raspberry, speckled alder, white pine, and red maple. Plants characteristic of wetlands grow near the edge of the water, including speckled alder, and sand bar willow. Water cress and *Fontinalis*, an aquatic moss, occur in some of the springs around the sinkhole. Table 4-131 lists the common species in the sinkhole. Depth to groundwater is 7 to 9.1 m (23 to 30 ft) bgs and groundwater flow is towards the sinkhole. Groundwater discharges from

all directions into the sinkhole. Several visible springs discharge water into the sinkhole. Water is present in the sinkhole year-round although human activities, such as the lowering of the Thunder Bay River, may dramatically impact the water level. The sinkhole serves as a water source for wildlife on the facility.

Identification of Chemicals of Potential Concern

Concentrations of chromium and copper were detected at levels above Act 307 Type B cleanup criteria in the surface water of the sinkhole. Copper, cadmium, chromium, lead, nickel, and zinc were detected in the groundwater at concentrations above Act 307 Type B GSI values. The sediment contained concentrations of arsenic, chromium, and selenium above Act 307 Type A criteria.

Identification of Exposure Pathways/Receptors

Air: Air is not identified as a exposure pathway for Site 4 because soils, which are the release source to air, were not addressed in the RI.

Surface Water: The potential release source and mechanism for the transport medium surface water is groundwater seepage of contaminated groundwater. Potential receptors are aquatic organisms, terrestrial wildlife, and birds. RI groundwater flow data indicate that groundwater, in which chemicals of concern were detected in concentrations above acceptable limits, is migrating toward the sinkhole. Chromium and copper were detected in the surface water collected at the point of entry from the ground, indicating that the surface water exposure pathway is complete. It is likely that the remaining groundwater contaminants cadmium, lead, nickel, and zinc will enter the sinkhole in the future in concentrations exceeding allowable limits.

Groundwater: The potential release mechanism and source for the transport medium groundwater is leaching of contaminated soils. The only potential receptors are plants whose primary exposure route would be uptake through their root system. However, groundwater at Site 4 is located at a depth greater than plant roots are likely to extend. This exposure pathway is currently, and most likely will remain, incomplete.

Soils: Soils at Site 4 are included in a source removal action plan (The Earth Technology Corporation, June 1994) and are not considered in this assessment.

Sediments: The potential release mechanism for sediment is site leaching. The potential source is contaminated groundwater. Aquatic organisms, terrestrial wildlife, birds, and plants are the potential receptors. The presence of arsenic, chromium, and selenium within the sediments of the sinkhole indicate this exposure pathway is currently complete for contaminated groundwater sources releasing chemicals of concern from Site 4 and other sites at the facility. Site 4 groundwater may become an additional contamination source in the future, releasing copper, cadmium, lead, nickel, and zinc to Site 4 sediments.

Ecological Hazard Assessment

The current and future exposure pathways and their associated receptors and chemicals of concern at Site 4 are identified in Table 4-127. The potential impacts upon ecological receptors from exposure to chemicals of concern originating from Site 4, are discussed below.

Arsenic: Arsenic is toxic to aquatic animal species, inducing its toxic effects via enzyme inhibition. In aquatic species, acute exposure has induced death and has caused death and deformity following chronic exposures. Bioconcentration occurs most frequently in invertebrates although arsenic can bioaccumulate in aquatic vertebrates. For freshwater aquatic organisms the acute lowest effective concentration is 3.6×10^2 µg/ℓ and the chronic lowest effective concentration is 1.9×10^2 µg/ℓ (IRIS, 1993). The toxicity value for oral exposure of rats to arsenic is 763 mg/kg and for mice 145 mg/kg (RTECS, 1993). Following acute oral exposure arsenic has been shown to induce death in wild rabbits and hares. Arsenic has been found to be carcinogenic, teratogenic, embryotoxic, and fetotoxic in laboratory species.

Cadmium: Chronic inhalation exposure of Wistar rats to cadmium produced lung tumors. Intratracheal instillation of cadmium oxide produced mammary tumors in female Fischar rats and tumors in multiple sites in males. Seven studies in rats and mice have shown that oral administration of cadmium slats resulted in no evidence of a carcinogenic response. Toxicity values for mice are 170 microgram(s)/m^3 (µg/m^3) for inhalation and 890 microgram(s) per kilogram (µg/kg) for oral exposure (RTECS,1993).

Aquatic species are the most sensitive group while mammals and birds are comparatively resistant. Cadmium has been found to bioaccumulate in the tissues of aquatic and marine organisms and has the potential to concentrate in the food chain (IRIS, 1993). For fish, the inhalation toxicity value is 100 (µg/m^3). Plant uptake of cadmium is not measurable at low levels in soils – uptake is greater by aerial deposition. Soil plant uptake is 5.5×10^{-1} (MEPAS). The toxicity value for the radish, lettuce, and red beet is 100 µg/kg, which results in reduced yields (Leeper, 1978). Numerous physical, chemical, and biological factors modify the uptake and retention of cadmium in all potential receptors.

Chromium: Chromium hazards to sensitive aquatic species have been documented at 10.0 ppb of hexavalent chromium. Records of acute toxicities to representative species of aquatic life have made it clear that hexavalent chromium is more toxic to freshwater biota in comparatively soft and acidic waters, that younger life stages are more sensitive than older organisms, and that 96 hours is insufficient to attain stable mortality patterns. (U.S. Department of the Interior, January 1986). A freshwater aquatic toxicity value was figured for hexavalent chromium. The lowest acute effective concentration, based on a one-hour average, is 1.6×10^1 µg/ℓ (IRIS, 1993). The lowest chronic effective concentration, based on a four-day average, is 1.1×10^1 µg/ℓ (IRIS, 1993). A toxicity value of 5 mg/kg may produce death in mice (CHR 85). The soil to plant uptake value for hexavalent chromium is 7.50×10^{-3} (MEPAS, 1989).

Copper: Copper has a low potential for biomagnification in the food chain. The inherent toxicity to animals is low and high to fish and plants. At low water alkalinity, toxicity of copper to aquatic life is enhanced. Mammals and birds have physiological barriers to copper absorption and are more resistant to copper toxicity than more primitive animals. The toxicity

Table 4-127 Current Exposure Pathways for Site 4
MIANG, Alpena CRTC, Alpena, Michigan

	Receptors				
Pathway	Terrestrial Wildlife	Birds	Plants	Aquatic Organisms	Chemicals of Concern
Air					
Surface Water	✓	✓		✓	Chromium, copper
Groundwater					
Soils					
Sediments	✓	✓	✓	✓	Arsenic, chromium, selenium

Future Potential Exposure Pathways for Site 4
MIANG, Alpena CRTC, Alpena, Michigan

	Receptors				
Pathway	Terrestrial Wildlife	Birds	Plants	Aquatic Organisms	Chemicals of Concern
Air					
Surface Water	✓	✓		✓	Cadmium, lead, nickel, zinc
Groundwater					
Soils					
Sediments	✓	✓	✓	✓	Copper, cadmium, lead, nickel, zinc

value of oral exposure of rats to copper ranges from 152 mg/kg to 1,520 μg/kg according to one study (Sax, 1984). For freshwater aquatic organisms the toxicity value has been found to be dependent upon water hardness. The acute lowest effective concentration was 9.2×10^{0} μg/ℓ and the chronic lowest effective concentration was 6.5×10^{0} μg/ℓ (IRIS, 1993). The soil to plant uptake value is 1.30×10^{-1} (MEPAS, 1989). Depression of growth in barley, snap beans, and tobacco occurred in whole shoots at concentrations exceeding 20 micrograms per gram (μg/g). The toxicity value for oats is 200 μg/g and for clover 100 μg/g.

Lead: Lead is generally considered a highly toxic contaminant because it is not an essential nutrient to either plants or animals. Lead bioaccumulates in animal tissues, but has a low potential for biomagnification in the food chain. The solubility of lead is dependent on water hardness, and is considered 20 to 100 times more toxic in soft water. In aquatic environments, most lead is found in bottom sediments and is; therefore, a concern more in benthic organisms than in planktonic or pelagic forms. Toxicity of lead in water is dependent on pH, organic materials, and the presence/absence of other metals. The primary mechanism of acute toxicity of lead to freshwater organisms is unknown. Invertebrate species appear more sensitive than vertebrate species. Lead inhibits plant growth and reduces photosynthesis, mitosis, and water absorption.

Mercury: Numerous biological and abiotic factors have been found to modify the toxicity of mercury compounds, sometimes by an order of magnitude or more, although the mechanisms of action are not clear. Toxicity in aquatic environments was found to be higher at elevated temperatures and in the presence of other metals such as zinc and lead (Eisler, 1987). Mercury toxicity to birds varies depending upon the form of the element, dose, route of administration, species, sex, age, and physiological condition. Acute oral toxicities of various mercury formulations ranged between 2.2 and around 31.0 mg/kg for most avian species tested (Eisler, 1987). Organomercury compounds, particularly methylmercury, have been found to be the most toxic mercury species tested. Among sensitive species of mammals, death occurred at daily organomercury concentrations of 1.0 to 5.0 mg/kg in the diet (Eisler, 1987). For reasons unknown, larger animals appear to be more resistant to mercury than smaller mammals.

Nickel: Although nickel is bioaccumulated, the concentration ratios reported for most freshwater organisms indicate that it is not a dominant fate process. Nickel has a low toxicity to aquatic life and a low potential to biomagnify in the food chain. Toxicity of nickel to aquatic life varies and is determined by water hardness, pH, the organism, and the chemical form of nickel. In general, nickels toxicity is increased five to ten times in soft water as compared to hard water. Vascular plants are known to accumulate nickel, but they also have been shown to have a high nickel tolerance.

Selenium: A toxicity value for rats exposed to selenium has been developed by RTECs. At 1 percent the effects may be inhibited growth, severe anemia, and death. The soil to plant uptake value is 4.00×10^{-1} (MEPAS, 1989). The amount of selenium taken up by plants for soil is generally dependent on several factors such as soil pH, temperature, and rainfall. The higher the temperature the greater the uptake. Plants from high rainfall areas have less selenium than plants growing in areas with low rainfall. The toxicity value for crop plants is 1-2 gram per milliliter(s) (g/ml) concentrations is soil solutions. The effects upon crop plants are diminished yields, black spots, interveinal chlorosis, and pink spots on roots (Aller, 1990).

Zinc: The toxicity values for rats through oral exposure ranges from 0.1 to 1 percent for zinc in their diet (Clayton and Clayton, 1981). At 0.5 percent rats capacity to reproduce may be reduced. At 1 percent the effects may be inhibited growth, severe anemia, and death. The soil to plant uptake value is 4.00×10^{-1} (MEPAS, 1989). The toxicity value for plants may be affected by pH in the soil. One study found that a pH of 5.5 may reduce wheat yields by 20 percent at a toxicity value of 20 eq/mil added as $ZnSO_4$ (Leeper, 1978). A toxicity value of 0.9 meg Zn/100 g soil in soil with a pH value of 6.1 caused plant damage to both swiss chard and spinach.

4.15.3.5 Site 5 Second Fire Training Area

Characterization of the Exposure Setting

Site 5, which occupies an area of approximately 4,940 m^2 (53,000 ft^2), is located within the training area of Alpena CRTC. The land surrounding Site 5 is used for combat training and is forested. A dump site for rocks and concrete is located on the northeast portion of the site and numerous areas of tree and brush piles are located throughout the site (see Figure 1-8). A few dirt roads run through the site. Site 5 is in an old field community dominated by grasses and weedy species such as spotted knapweed, common mullein, white clover, yellow clover, sweet fern, yarrow, bladder campion, and blackberry. Table 4-131 lists the common species of this site. Beyond the old field community a dry-mesic northern forest is to the west, south, and north; and a dry northern forest is to the east. Further to the north and west are deep marsh wetlands associated with the Thunder Bay River. The soils at Site 5 will be remediated under a source removal action and are not considered in this risk assessment. Lake Winyah lies approximately 305 m (1,000 ft) to the northwest of Site 5. Groundwater beneath the site consists of a surficial aquifer present at approximately 1.8 m (6 ft) bgs. A groundwater mound beneath the site directs the surficial groundwater radially away from the mound. Groundwater flows southeast towards the sinkhole at the southern end of the site and at the northern end of the site, groundwater flows to the northwest to Lake Winyah.

Identification of Chemicals of Potential Concern

Copper, chromium, lead, nickel, and zinc were detected in the groundwater at concentrations above Act 307 Type B GSI values.

Identification of Exposure Pathways/Receptors

Air: Air is not identified as a exposure pathway for Site 4 because soils, which are the release source to air, were not addressed in the RI.

Surface Water: The potential release source and mechanism to surface water is groundwater seepage of contaminated groundwater. RI groundwater flow data indicate that groundwater is migrating toward the sinkhole and Lake Winyah. Based on groundwater modeling data, the estimated maximum concentrations of copper (sinkhole 1.5 ppb, Lake Winyah 0.09 ppb), chromium (sinkhole 1.6 ppb, Lake Winyah 0.1 ppb), lead (sinkhole 0.9 ppb, Lake Winyah 0.05 ppb), nickel (sinkhole 1.4 ppb, Lake Winyah 0.9 ppb), and zinc (sinkhole 5.1 ppb, Lake Winyah 0.3 ppb) discharged to the sinkhole and Lake Winyah will be below Act 307 GSI criteria. There is no complete groundwater exposure pathway. The current groundwater exposure pathway is not complete. Should it become complete in the future, the concentrations of chemicals of concern are estimated to be below levels which will adversely affect environmental receptors.

Groundwater: The potential release mechanism and source to groundwater is leaching of contaminated soils. The only potential receptors are plants whose primary exposure route would be their root system. However, groundwater at Site 5 is located at a depth greater than plant roots are likely to extend; therefore, there is no complete pathway of exposure for groundwater.

Soils: A focused feasibility study is planned for the soils at Site 5 and; therefore, soils are not included in this assessment.

Sediments: The potential release mechanism for sediment is site leaching. The potential source is contaminated groundwater. Aquatic organisms, terrestrial wildlife, birds, and plants are the potential receptors. Groundwater from beneath the site containing contaminants of concern will not pose an exposure potential because their maximum concentration in the sinkhole and Lake Winyah is not expected to go above Act 307 criteria.

Ecological Hazard Assessment

None of the exposure pathways at Site 5 are presently complete, and it is anticipated that should they become complete in the future the concentrations of chemicals of concern released wil not adversely affect environmental receptors.

4.15.3.6 Site 6 Former Solid Waste Landfill and Site 7 First Fire Training Area

Characterization of the Exposure Setting

Sites 6 and 7 lie within the training area of the Alpena CRTC (see Figure 1-9). Site 6 is a landfill which extends over approximately 20,007 m^2 (214,700 ft^2) and is primarily grass-covered, with the exception of one section in which a large cluster of tabular rushes exist. Now an old field community, Site 6 is dominated by weedy species such as spotted knapweed, alfalfa, black oak seedlings, bracken, sweet fern, balsam poplar, and grasses. Table 4-131 lists the common species in Site 6. Site 7 is located on the road adjacent to Site 6 and is approximately 1,866 m^2 (20,021 ft^2) in area. The road is covered with sand and gravel. Directly west of these two sites are deep marsh wetlands associated with the backwater area of Lake Winyah. The facility wastewater treatment plant lies to the south of the site. Areas to the north and east consist of dry-mesic northern hardwoods. The groundwater beneath the sites consist of a shallow aquifer at 3 to 5.8 m (10 to 19 ft) bgs. A groundwater divide exists across Site 6 which separates water flowing southeast to the sinkhole and water flowing northwest into the backwater area of Lake Winyah and the Thunder Bay River. Water in the backwater area appears to be stagnant.

Identification of Chemicals of Potential Concern

Concentrations of copper, chromium, lead, cadmium, selenium, mercury, and zinc were detected in groundwater above Act 307 cleanup criteria. Lead, selenium, chrysene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and benzo(k)fluoranthene were detected in sediments at concentrations above the Michigan Act 307 criteria.

Identification of Exposure Pathways/Receptors

Air: The potential release mechanism and source for the transport medium air at Sites 6 and 7 is volatilization of contaminants in soils. The potential receptors would be terrestrial wildlife, birds, and the plant community whose primary exposure route would be inhalation. No volatile or semivolatile compounds were detected in the soil above Act 307 Type B cleanup criteria; therefore, air is not a current or future exposure pathway.

Surface Water: The potential release sources and mechanisms for the transport medium surface water are surface runoff from contaminated surface soils and groundwater seepage of contaminated groundwater. No chemicals of concern were detected in surface soils; therefore, this is not a release source. RI groundwater flow data indicate that groundwater, in which chemicals of concern were detected, is migrating toward the sinkhole and the backwater area of Lake Winyah. Based on groundwater modeling data, the estimated maximum concentrations of copper (3.3 ppb), cadmium (0.35 ppb), lead (2.5 ppb), selenium (5.0 ppb), and zinc (10.98 ppb) discharged to the sinkhole will be below Act 307 GSI criteria. Contaminant concentrations in the backwater of Lake Winyah were considered to be essentially the same as those detected in groundwater monitoring well LF6MW10 because it is located immediately adjacent. Chemicals of concern detected above Act 307 criteria in this well were chromium (60.5 ppb), copper (57.8 ppb), lead (127.0 ppb), mercury (0.36 ppb), and zinc (258.0 ppb). The release source groundwater has completed the surface water exposure pathway.

Groundwater: The potential release mechanism and source for the transport medium groundwater is leaching of contaminated soils. The only potential receptors are plants whose primary exposure route would be their root system. However, groundwater at the two sites is located at a depth greater than plant roots are likely to extend. This exposure pathway is currently, and most likely will remain, incomplete.

Soils: Potential release mechanisms of soil are leaching into the groundwater, tracking by mammals, and fugitive dust generation. Potential receptors are terrestrial wildlife, birds, and plants. The primary exposure routes are oral consumption, dermal contact, and uptake by plant root systems. Soils are not a current or future potential pathway because no chemicals of concern were detected in the soils of Site 6 and 7.

Sediments: The potential release mechanisms for sediment are site leaching and tracking. The potential sources are contaminated groundwater and surface soil. Aquatic organisms, terrestrial wildlife, birds, and plants are the potential receptors. The presence of lead, selenium, chrysene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and benzo(k)fluoranthene within the sediments of the sinkhole indicate this exposure pathway is complete. Additional groundwater contaminants may enter the sediment exposure pathway in the future.

Ecological Hazard Assessment

The current and future exposure pathways and their associated receptors and chemicals of concern at Sites 6 and 7 are identified in Table 4-128. The potential impacts upon ecological receptors from exposure to copper, mercury, selenium, and zinc are addressed in

Table 4-128 Current Exposure Pathways for Sites 6 and 7
MIANG, Alpena CRTC, Alpena, Michigan

	Receptors				
Pathway	Terrestrial Wildlife	Birds	Plants	Aquatic Organisms	Chemicals of Concern
Air					
Surface Water	✓	✓		✓	Chromium, copper, lead, mercury, zinc
Groundwater					
Soils					
Sediments	✓	✓	✓	✓	Lead, selenium, chyrsene, benzo(a)anthracence, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene

Future Potential Exposure Pathways for Sites 6 and 7
MIANG, Alpena CRTC, Alpena, Michigan

	Receptors				
Pathway	Terrestrial Wildlife	Birds	Plants	Aquatic Organisms	Chemicals of Concern
Air					
Surface Water					
Groundwater					
Soils					
Sediments	✓	✓	✓	✓	Chromium, copper, lead mercury, zinc

wp/t4-128.775-06/15/95

Section 4.15.3.4. Exposure to chrysene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and benzo(k)fluoranthene are addressed in Section 4.15.3.3. Exposure of ecological receptors to lead is discussed below.

Chromium: Chromium hazards to sensitive aquatic species have been documented at 10.0 ppb of hexavalent chromium. Records of acute toxicities to representative species of aquatic life have made it clear that hexavalent chromium is more toxic to freshwater biota in comparatively soft and acidic waters, that younger life stages are more sensitive than older organisms, and that 96 hours is insufficient to attain stable mortality patterns. (U.S. Department of the Interior, January 1986). A freshwater aquatic toxicity value was figured for hexavalent chromium. The lowest acute effective concentration, based on a one-hour average, is 1.6×10^{1} μg/ℓ (IRIS, 1993). The lowest chronic effective concentration, based on a four-day average, is 1.1×10^{1} μg/ℓ (IRIS, 1993). A toxicity value of 5 mg/kg may produce death in mice (CHR 85). The soil to plant uptake value for hexavalent chromium is 7.50×10^{-3} (MEPAS, 1989).

Copper: Copper has a low potential for biomagnification in the food chain. The inherent toxicity to animals is low and high to fish and plants. At low water alkalinity, toxicity of copper to aquatic life is enhanced. Mammals and birds have physiological barriers to copper absorption and are more resistant to copper toxicity than more primitive animals. The toxicity value of oral exposure of rats to copper ranges from 152 mg/kg to 1,520 μg/kg according to one study (Sax, 1984). For freshwater aquatic organisms the toxicity value has been found to be dependent upon water hardness. The acute lowest effective concentration was 9.2×10^{0} μg/ℓ and the chronic lowest effective concentration was 6.5×10^{0} μg/ℓ (IRIS, 1993). The soil to plant uptake value is 1.30×10^{-1} (MEPAS, 1989). Depression of growth in barley, snap beans, and tobacco occurred in whole shoots at concentrations exceeding 20 μg/g. The toxicity value for oats is 200 μg/g and for clover 100 μg/g.

Lead: Generally, organic lead compounds are more toxic than inorganic lead compounds. Biomagnification in the food chain is negligible and younger, immature organisms are most susceptible. Adverse effects of uptake of lead by terrestrial plants seems to occur only at total concentrations of several hundred mg lead/kg soil (Eisler, 1988). In aquatic environments, dissolved waterborne lead was found to be more toxic than total lead and organic lead compounds were more toxic than inorganic forms. For all aquatic species the effects of lead were found to be most pronounced at elevated water temperatures and reduced pH; in comparatively soft waters; in younger life stages; and after long exposures. Ingestion of spent lead shot by migratory waterfowl and other birds is a significant cause of mortality in these species, and also in raptors that eat the waterfowl killed or wounded by hunters. Except for certain alkyllead compounds that bioconcentrate in aquatic food items, forms of lead other than shot are unlikely to cause clinical signs of lead poisoning in birds. Among sensitive species of mammals, survival was reduced at acute oral doses as low as 5 mg/kg in rats, chronic oral doses of 0.3 mg/kg in dogs, and dietary levels of 1.7 mg/kg in horses (Eisler, 1988).

Mercury: Numerous biological and abiotic factors have been found to modify the toxicity of mercury compounds, sometimes by an order of magnitude or more, although the mechanisms of action are not clear. Toxicity in aquatic environments was found to be higher at elevated temperatures and in the presence of other metals such as zinc and lead (Eisler, 1987). Mercury toxicity to birds varies depending upon the form of the element, dose, route of

administration, species, sex, age, and physiological condition. Acute oral toxicities of various mercury formulations ranged between 2.2 and around 31.0 mg/kg for most avian species tested (Eisler, 1987). Organomercury compounds, particularly methylmercury, have been found to be the most toxic mercury species tested. Among sensitive species of mammals, death occurred at daily organomercury concentrations of 1.0 to 5.0 mg/kg in the diet (Eisler, 1987). For reasons unknown, larger animals appear to be more resistant to mercury than smaller mammals.

PAHs: Inter and intraspecies responses to PAHs are quite variable, and are significantly modified by other chemicals including other PAHs. PAHs cause embryotoxicity when applied to the surface of mallard eggs. There is a scarcity of data on PAH background. PAHs show little tendency for bioaccumulation, despite their high lipid solubility. Amphibians are quite resistant to PAH carcinogenesis when compared to mammals. There are sufficient data to confirm animal carcinogenicity for chrysene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and indeno(1,2,3-c,d)pyrene (IRIS, March 1993). Terrestrial plants can absorb PAHs from soils through their roots, and translocate them to other parts of the plant. Uptake rates are governed by PAH concentration, solubility, soil type, and PAH physiochemical state. Low molecular weight PAHs absorbed more readily than those with higher molecular weight. PAH induced phytotoxic effects are rare and not well documented. PAHs persist in the soil for a long time and are not taken up by plants to an appreciable extent. Soil to plant uptakes are 5.61×10^{-3} for benzo(a)anthracene, 3.04×10^{-3} for benzo(a)pyrene, 3.04×10^{-3} for benzo(b)fluoranthene, 3.04×10^{-3} for benzo(k)fluoranthene, and 5.54×10^{-3} for chrysene (MEPAS, 1989).

Selenium: A toxicity value for rats exposed to selenium has been developed by RTECs. The At 1 percent the effects may be inhibited growth, severe anemia, and death. The soil to uptake value is 4.00×10^{-1} (MEPAS, 1989). The amount of selenium taken up by plants for soil is generally dependent on several factors such as soil pH, temperature, and rainfall. The higher the temperature the greater the uptake. Plants from high rainfall areas have less selenium than plants growing in areas with low rainfall. The toxicity value for crop plants is 1-2 g/ml concentrations is soil solutions. The effects upon crop plants are diminished yields, black spots, interveinal chlorosis, and pink spots on roots (Aller, 1990).

Zinc: The toxicity values for rats through oral exposure ranges from 0.1 to 1 percent for zinc in their diet (Clayton and Clayton, 1981). At 0.5 percent rats capacity to reproduce may be reduced. At 1 percent the effects may be inhibited growth, severe anemia, and death. The soil to plant uptake value is 4.00×10^{-1} (MEPAS, 1989). The toxicity value for plants may be affected by pH in the soil. One study found that a pH of 5.5 may reduce wheat yields by 20 percent at a toxicity value of 20 eq/mil added as $ZnSO_4$ (Leeper, 1978). A toxicity value of 0.9 meg Zn/100 g soil in soil with a pH value of 6.1 caused plant damage to both swiss chard and spinach.

4.15.3.7 Site 8 Former Site of Hangar 9

Characterization of the Exposure Setting

Site 8 is the former site of Hangar 9 and covers an area of approximately 12,906 m^2 (138,500 ft^2) (see Figure 1-10). The concrete foundation is all that remains of the hangar.

The site lies within a developed portion of the facility. This development consists mostly of paved roads, although a portion of Building 321 and 320 are within the site boundaries. There is a small area of grass and ornamental plantings such as northern white cedar, shrubby cinquefoil, and marigolds. North and west of Site 8 is the developed portion of the facility consisting of roads and buildings. South and east of the site are the taxiways and runways. This site extends to the north west into mowed areas dominated by grasses, black oak, and jack pine. Depth to the water table varies from 3 to 5.5 m (10 to 18 ft) below ground surface. The direction of shallow groundwater flow beneath Site 8 is northwest towards the sinkhole.

Identification of Chemicals of Potential Concern

Concentrations of antimony and lead were found in the surface soils at concentrations above Act 307 Type A criteria. Copper, chromium, lead, nickel, diethyl phthalate, and zinc were found in the groundwater at a concentrations above Act 307 Type B GSI values.

Identification of Exposure Pathways/Receptors

Air: The potential release mechanism and source for the transport medium air is volatilization of contaminates in soils. The potential receptors would be terrestrial wildlife, birds, and the plant community whose primary exposure route would be inhalation. No volatile or semivolatile compounds were detected in the soil above Act 307 Type B criteria therefore, air is not a current or future exposure pathway.

Surface Water: The potential release sources and mechanisms for the transport medium surface water are surface runoff from contaminated surface soils and groundwater seepage of contaminated groundwater. Potential receptors are aquatic organisms, terrestrial wildlife, and birds. Although surface runoff could be a transport mechanism for contaminated surface soil, there is no surface water body located close enough to the site for surface soils to enter. Based on groundwater modeling data, the estimated maximum concentrations of copper (0.02 ppb), chromium (0.02 ppb), lead (0.02 ppb), nickel (0.028 ppb), and zinc (0.06 ppb) discharged to the sinkhole will be below Act 307 GSI criteria. No GSI value has been determined for the analyte diethyl phthalate which has an estimated maximum concentration of 0.0008 ppb.

Groundwater: The potential release mechanism and source for the transport medium groundwater is leaching of contaminated soils. The only potential receptors are plants whose primary exposure route would be by root uptake. Groundwater at Site 8 is located at a depth greater than plant roots are likely to extend. This exposure pathway is currently, and most likely will remain, incomplete.

Soils: Potential soil release mechanisms are leaching into groundwater, tracking by animals and people, and fugitive dust generation. Potential receptors are terrestrial wildlife, birds, and plants. The primary exposure routes are oral consumption, dermal contact, and uptake by plant root systems. The current pathway for exposure to chemicals of concern within the soils at Site 8 is complete for all receptors because antimony and lead were detected in surface soils.

Primary consumers would be the most highly impacted terrestrial organisms. The threat to secondary consumers would be exposure to contaminants in the systems of the primary consumers through consumption of the primary consumer. However, the fairly high level of human activity at Site 8 would most likely discourage the presence of predators at the site, lessening the threat of exposure to secondary consumers.

Sediments: The potential release mechanisms for sediment are site leaching and tracking. The potential sources are contaminated groundwater and surface soil. Aquatic organisms, terrestrial wildlife, birds, and plants are the potential receptors. The current exposure pathway is not complete for the groundwater source because the estimated maximum contaminant concentrations will be below Act 307 GSI criteria for the sinkhole. The distance is too great for the transport of surface soil contaminants to sinkhole sediments so that this pathway is also incomplete. Site 8 groundwater may become an exposure pathway for the release of diethyl phthalate to the sinkhole in the future.

Ecological Hazard Assessment

The current and future exposure pathways and their associated receptors and chemicals of concern at Site 8 are identified in Table 4-129. The potential impacts upon ecological receptors from exposure to antimony are discussed below.

Antimony: For rats an oral toxicity value producing death was found to be 7 gm/kg (RTECs). For oral exposure through drinking water, a toxicity value of 5 ppm of potassium antimony tartrate significantly reduced the lifespan of mice and rats, with the degree of toxicity more severe is rats (IRIS, 1992). The soil to plant uptake value for antimony is 1.10×10^{-2} (MEPAS, 1989).

Lead: Generally, organic lead compounds are more toxic than inorganic lead compounds. Biomagnification in the food chain is negligible and younger, immature organisms are most susceptible. Adverse effects of uptake of lead by terrestrial plants seems to occur only at total concentrations of several hundred mg lead/kg soil (Eisler, 1988). In aquatic environments, dissolved waterborne lead was found to be more toxic than total lead and organic lead compounds were more toxic than inorganic forms. For all aquatic species the effects of lead were found to be most pronounced at elevated water temperatures and reduced pH; in comparatively soft waters; in younger life stages; and after long exposures. Ingestion of spent lead shot by migratory waterfowl and other birds is a significant cause of mortality in these species, and also in raptors that eat the waterfowl killed or wounded by hunters. Except for certain alkyllead compounds that bioconcentrate in aquatic food items, forms of lead other than shot are unlikely to cause clinical signs of lead poisoning in birds. Among sensitive species of mammals, survival was reduced at acute oral doses as low as 5 mg/kg in rats, chronic oral doses of 0.3 mg/kg in dogs, and dietary levels of 1.7 mg/kg in horses (Eisler, 1988).

Diethyl phosphate: Research conducted on the oral exposure of rats to diethyl phthalate found that reproductive performance after oral administration of 0.25, 1.25, and 2.5 percent for 18 weeks did not appear to have any adverse affects. Second-generation breeding pairs exhibited increased right epididymis and prostate weights in males and decreased pituitary weight in females after exposure to 2.5 percent diethyl phthalate. Another study found no changes in behavior or other clinical signs of toxicity in rats after prolonged oral exposure.

Table 4-129 Current Exposure Pathways for Site 8
MIANG, Alpena CRTC, Alpena, Michigan

	Receptors				
Pathway	Terrestrial Wildlife	Birds	Plants	Aquatic Organisms	Chemicals of Concern
Air					
Surface Water					
Groundwater					
Soils	✓	✓	✓		Antimony, lead
Sediments					

Future Potential Exposure Pathways for Site 8
MIANG, Alpena CRTC, Alpena, Michigan

	Receptors				
Pathway	Terrestrial Wildlife	Birds	Plants	Aquatic Organisms	Chemicals of Concern
Air					
Surface Water	✓	✓		✓	Diethyl phthalate
Groundwater					
Soils					
Sediments	✓	✓	✓	✓	Diethyl phthalate

wp/t4-129.775-06/15/95

A significant decrease in weight gain was noted throughout the study in both sexes given 5 percent diethyl phthalate (15 to 25 percent decreases) and in females (5 to 8 percent decrease) fed 1 percent diethyl phthalate (IRIS, 1993).

Acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 940 and 3 $\mu g/\ell$, respectively, and would occur at lower concentrations among more sensitive species that were not tested (EPA, 1986).

4.15.3.8 Site 9 Radar Tower Site

Characterization of the Exposure Setting

Site 9, the radar tower site, occupies an area of approximately 37,787 m^2 (405,500 ft^2) (see Figure 1-11). The northern portion of the site is fairly undeveloped with only a few buildings present. This site is partially developed. The northern third of the site supports a dry northern forest dominated by jack pine, black oak, trembling aspen, balsam fir, blueberry, and bracken. The common species in site 9 are listed in Table 4-131. Site 9 is bordered on the east, south, and west by other developed parts of the Alpena CRTC. The northern part of Site 9 is bordered by a continuation of the dry northern forest in the northern third of this site. North of the gravel road is forested area which extends north of the site boundaries. The southern portion of the site is highly developed with numerous buildings and roads present with some grassy areas with jack pine and black oak trees. The depth to shallow groundwater at Site 9 is 4.3 to 7.3 m (14 to 24 ft) bgs and flows north toward the sinkhole. The sinkhole is approximately 305 m (1,000 ft) from Site 9.

Identification of Chemicals of Potential Concern

Copper, chromium, lead, nickel, naphthalene, 1,2-dimethylbenzene, 1,3-dimethybenzene, 1,4-dimethylbenzene, 1,4-dichlorobenzene, and zinc were detected in groundwater at Site 9 in concentrations above Act 307 Type B GSI values.

Identification of Exposure Pathways/Receptors

Air: The potential release mechanism and source for the transport medium air is volatilization of contaminated soils. The potential receptors would be terrestrial wildlife, birds, and the plant community whose primary exposure route would be inhalation. No volatile or semivolatile compounds were detected in soils above Act 307 Type B criteria therefore, air is not a current or future exposure pathway.

Surface Water: The potential release sources and mechanisms for the transport medium surface water are surface runoff from contaminated surface soils and groundwater seepage of contaminated groundwater. Potential receptors are aquatic organisms, terrestrial wildlife, and birds. No chemicals of concern were detected in surface soil therefore this is not a release source. RI groundwater flow data indicate that groundwater, in which chemicals of concern were detected, is migrating toward the sinkhole. Based on groundwater modeling data, the estimated maximum concentrations of copper (0.03 ppb), chromium (0.03 ppb), lead (0.08 ppb), nickel (0.02 ppb), naphthalene (0.01 ppb), 1,4-dichlorobenzene (0.005 ppb), and

zinc (0.07 ppb) discharged to the sinkhole will be below Act 307 GSI criteria. No GSI values have been determined for the analytes 1,2-dimethylbenzene (0.28 ppb), 1,3-dimethylbenzene (0.27 ppb), and 1,4-dimehthylbenzene (0.17 ppb).

Groundwater: The potential release mechanism and source for the transport medium groundwater is leaching of contaminated soils. The only potential receptors are plants whose primary exposure route would be their root system. However, the groundwater at Site 9 is located at a depth greater than plant roots are likely to extend. This exposure pathway is currently, and most likely will remain, incomplete.

Soils: Potential release mechanisms soil are leaching into the groundwater, tracking by mammals, and fugitive dust generation. Potential receptors are terrestrial wildlife, birds, and plants. The primary exposure routes are oral consumption, dermal contact, and uptake by root systems. Soils are not a current or future potential pathway because no chemicals of concern were detected in the site soils.

Sediments: The potential release mechanisms for sediment are site leaching and tracking. The potential sources are contaminated groundwater and surface soil. Aquatic organisms, terrestrial wildlife, birds, and plants are the potential receptors. Surface soils are not a potential contamination source because no chemicals of concern were found in concentrations above acceptable limits. Groundwater from beneath the site containing chemicals of concern has not yet reached the sinkhole so that the groundwater source is not currently present and the sediment exposure pathway is not complete. The sediment pathway would become complete should groundwater discharge to the sinkhole in the future.

<u>Ecological Hazard Assessment</u>

Currently, no exposure pathways are complete at Site 9. The future exposure pathways and their associated receptors and chemicals of concern at Site 9 are identified in Table 4-130. The potential impacts upon ecological receptors from exposure to 1,2-dimethylbenzene, 1,3-dimethylbenzene, and 1,4-dimethylbenzene are discussed below as xylenes.

Xylenes: Bioconcentration of xylenes is not expected to be significant (Howard, 1990). There are inadequate data to confirm animal carcinogenicity (IRIS, 1993). Rats and mice exposed to 250 μg/kg per day of total xylene experienced hyperactivity, decreased body weight and increased mortality (IRIS, 1993). The soil to plant uptake for a mixture of xylenes is 1.26×10^{-1} (MEPAS, 1989).

Table 4-130 Future Potential Exposure Pathways for Site 9
MIANG, Alpena CRTC, Alpena, Michigan

	Receptors				
Pathway	Terrestrial Wildlife	Birds	Plants	Aquatic Organisms	Chemicals of Concern
Air					
Surface Water	✓	✓		✓	1,2-dimethylbenzene, 1,3-dimethylbenze, 1,4-dimethylbenzene
Groundwater					
Soils					
Sediments	✓	✓	✓	✓	1,2-dimethylbenzene, 1,3-dimethylbenze, 1,4-dimethylbenzene

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5.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A RI has been completed under the IRP for the Alpena CRTC, Michigan ANG, Alpena, Michigan. A presentation of the summary and conclusions obtained from an evaluation of the hydrogeologic investigations, the field sampling programs, and the results of the ecological and human health risk assessments are included in the following subsections. A summary of the results for each site is presented in Section 5.1. Conclusions and recommendations are presented in Section 5.2

5.1 SUMMARY

The nine sites investigated during this RI are listed below:

Site 1: Old POL Storage Area
Site 2: Motor Pool Area
Site 3: Former Site of County Garage
Site 4: Third Fire Training Area
Site 5: Second Fire Training Area
Site 6 and Site 7: Former Solid Waste Landfill and First Fire Training Area
Site 8: Former Site of Hangar 9
Site 9: Radar Tower Site

This section presents a summary of the data collected for each site. The results of the ecological and human health risk assessment are also summarized in the following subsections for each site.

5.1.1 Facility-wide Geology and Hydrogeology

Unconsolidated, sand-rich sediments comprise the surficial geologic deposits beneath the facility. Sites 1, 5, and 6/7 are all located adjacent to the Thunder Bay River or to the backwaters of Lake Winyah and have a component of groundwater flow towards these surface water bodies. The shallow materials beneath these sites are more clay-rich than the remaining sites. Groundwater comprising the shallow aquifer occurs within these surficial deposits at depths ranging from approximately .6 to 7.6 m (2 to 25 ft) bgs, and in general, flows towards the sinkhole which is located in the north-central portion of the facility. The surficial aquifer is underlain by a limestone bedrock aquifer. This bedrock aquifer is used as a source of domestic water in the area surrounding the facility. At Sites 1, 2, and 3, a clay layer (greater than .3 m [1 ft] thick) separating the shallow aquifer from the bedrock aquifer was observed during the drilling operations. Rather than occurring immediately above the limestone bedrock, the clay layer beneath Site 1 occurs within the shallow aquifer and has separated the shallow aquifer into a perched and lower sand zone. No well-defined clay layer was observed during drilling operations beneath Sites 4, 5, 6/7, 8, and 9. The hydraulic head distribution (groundwater elevation) and flow direction in the bedrock aquifer beneath the facility is unknown.

5.1.2 Quality Assurance/Quality Control

A detailed QA/QC program was instituted to ensure the sampling and analysis completed during the RI were representative of the sites under investigation. All fixed-base laboratory samples were collected and analyzed using HAZWRAP QC Level C (equivalent to EPA Level 3 QC) requirements. A review of these procedures and the control data indicate, in general, the objectives outlined by the PARCC parameters (Section 2.10.1) have been met. However, some samples failed to meet required QA criteria. Several samples failed the required laboratory QC requirements which resulted in the validation of affected compounds as R, indicating unreliable data. Several compounds detected in trip, equipment, and laboratory blanks may be attributed to sampling handling, transportation, storage, or analytical procedures. A majority of the groundwater samples which contained detectable concentrations of TPH (as reported by the laboratory) were qualified B, because of TPH concentrations reported in the ASTM Type II water produced on site.

5.1.3 Site 1: Summary

Site 1 consisted of various aboveground storage tanks, associated distribution lines, and dispensers. The Site 1 POL area was used between 1952 and July 1987, when it was dismantled and the new POL area west of Site 9 was put into use. Petroleum-based fuels have probably been released into the subsurface environment from the aboveground storage tanks, fuels offloading area, and the dispensers previously located at Site 1. The results of the investigations are summarized in the following paragraphs.

Geology and Hydrogeology

Soils at Site 1 are predominantly composed of quartz sand. An intermediate depth clay layer occurs at depths between approximately 3 and 5.5m (10 and 18 ft) bgs and separates the shallow aquifer into a perched zone and a lower unconfined zone. No clay unit directly overlying the limestone bedrock was observed at location S1MW1. Groundwater occurs at depths between approximately 0.6 and 1.5m (2 and 5 ft) bgs beneath the site. Groundwater flow within the perched zone is west towards the river, and north and northeast towards Site 2.

Soil Analytical Results

Surface and subsurface soils collected from Site 1 are relatively free of compounds exceeding the Act 307 Type A or B cleanup criteria. Soil samples from a depth of 0.6 to 0.9m (2 to 3 ft) in SB1 contain chlorobenzene, ethylbenzene, and styrene at concentrations exceeding Act 307 Type B cleanup criteria. These soil samples were collected in the west central portion of the site in an area where several aboveground jet fuel storage tanks once stood. No inorganics were detected in any soil samples in concentrations exceeding Act 307 Type A default metals cleanup criteria.

Sediment Analytical Results

Sampling results do not indicate that past fuel-handling activities at Site 1 have had an adverse impact on sediment quality in the Thunder Bay River.

Groundwater Analytical Results

Free phase hydrocarbons (i.e. JP-4) were not detected floating on top of the groundwater in the three piezometers installed within the suspected source areas at Site 1. However, VOCs were detected in both the perched and lower sand layers of the shallow aquifer. VOCs, particularly benzene, were detected in concentrations exceeding Act 307 Type B cleanup criteria in the groundwater samples collected and analyzed from wells S1MW1 and S1MW6 which are completed in the perched zone of the shallow aquifer. The analytical data obtained from S1MW14 suggests that some vertical migration of VOCs has probably occurred through the clay layer. Sampling data collected during the RI indicates that the lower zone of the shallow aquifer does contain bromodichloromethane and dibromochloromethane in concentrations exceeding their respective Act 307 Type B cleanup criteria. Bromodichloromethane and dibromochloromethane were not quantified in Site 1 surface and subsurface soils collected during the investigations.

Baseline Risk Assessment Results

Chemicals of potential concern at Site 1 were evaluated for the groundwater, surface water, and soil pathways. Chemicals of potential concern were identified based on occurrence above MDNR Act 307 Type A or B cleanup criteria. Under Act 307, those chemicals occurring above Type A or B cleanup criteria require a site-specific risk assessment as part of Type C cleanup criteria.

Chemicals of potential concern present in the groundwater include benzene, antimony, bromodichloromethane, dibenzofuran, 1,4 dichlorobenzene, styrene, and carbon tetrachloride. Chemicals present in the groundwater were also evaluated as chemicals of concern for the surface water pathways under the future land-use scenario. No surface water chemicals of concern were identified under the current land-use scenario. Ethylbenzene, chlorobenzene, and styrene were evaluated as chemicals of potential concern in the subsurface soil. No chemicals of concern are present in the surface soil.

Exposure scenarios evaluated include the present use of the land by the ANG (including recreational activities) future use of the land by the ANG, and future use of the land as a solely recreational facility (parks, camps, etc.). The most reasonably exposed populations include the current on-site employees and current recreational child and the future on-site employee, future excavation worker, and future recreational child and adult. A worst-case scenario was evaluated for the adult by assuming the adult worked at the facility and also participated in weekend recreational activities.

No complete current exposure pathways were identified at Site 1. The complete future pathways include Thunder Bay River surface water pathways (ingestion, dermal absorption, and fish consumption) and shallow aquifer production well (PW3) pathways (ingestion, dermal absorption, and inhalation of VOCs).

Carcinogenic and noncarcinogenic exposures were evaluated for all scenarios. Based on MDNR guidance, a reference level of 1×10^{-6} for carcinogens was used to evaluate the cancer risks. Cancer risks were summed for individual chemicals in a pathway and total pathway risks were then summed to provide an overall risk. The results indicate that no chemicals of concern in the Thunder Bay River surface water provide a future exposure risk above 1×10^{-6} for the on-site adult (participating in recreational activities) and the recreational child (through ingestion, dermal absorption, and fish consumption). No slope factors were available for chemicals of concern in the soil, consequently no cancer risk was calculated for the future excavation worker. No future cancer risk exceeding 1×10^{-6} exists for the recreational child through the future use of PW3 as a domestic water source. A total cancer risk equal to, but not exceeding 1×6^{-6} was calculated for the future on-site adult. The risk attributable to the ingestion of groundwater from PW3 is equal to 1×10^{-6}, with carbon tetrachloride contributing 95% of the risk.

The RfD was considered the reference level for noncarcinogens, based on EPA guidance. HQs are the ratio of the calculated exposure to the RfD. Quotients greater than unity represent concern for noncarcinogenic effects. HQs were summed for all pathways to provide a pathway HI and all pathways were summed to provide a total exposure HI.

Results indicate HQs, pathway HIs, and total exposure HIs below 1 for the current and future on-site adult and recreational child. Subchronic HQs above 1 were calculated for chlorobenzene for the pathway inhalation of VOCs from soil for the excavation worker. The HQ above 1 indicates that some form of personal protective equipment may be required during excavation at the site.

Uncertainties in the calculated carcinogenic and noncarcinogenic risks were evaluated. The major area of uncertainty is the calculated inhalation intake for the inhalation of VOCs from soil. The model assumes a uniform concentration throughout the site and no clean soil cap. In reality, the VOCs detected in the soil are limited to one area of the site, and the VOCs volatilized to the air will decrease as soil layers lose their VOCs through progressively thick layers.

Environmental Assessment Results

A qualitative evaluation was performed of risks to the natural environment posed by chemicals of concern at Site 1. Chemicals above Act 307 Type A cleanup criteria for soils and above Act 307 GSI values in water were identified and potentially complete pathways evaluated. Chemicals of concern for the currently complete air and soil exposure pathways are chlorobenzene, ethylbenzene, and styrene. Potential receptors include terrestrial wildlife, birds, and plants. Chemicals of concern for the surface water, groundwater, and sediment pathways are chromium, lead, and zinc. Potential receptors include terrestrial wildlife, birds, plants, and aquatic organisms at Lake Winyah. No future exposure pathways for additional chemicals of concern were identified.

5.1.4 Site 2: Summary

Site 2, the Motor Pool Area, includes Building 7 (Vehicle Maintenance Shop) and the refueling area for facility vehicles. The following summarizes the findings of the subsurface investigations completed for Site 2.

Geology and Hydrogeology

Shallow aquifer materials beneath Site 2 are composed of quartz sand. The sand section is approximately 16.8 m (55 ft) thick. Below the sand, a clay aquitard at least 3 m (10 ft) in thickness separates the shallow aquifer from the limestone bedrock aquifer.

Soil Analytical Results

Source areas at the site investigated by the soil sampling program include the vehicle maintenance shop (Building 7), the USTs within the facility refueling area, and the area around MP2MW1 (located outside the Site 2 boundaries). Only one soil sample contained a compound exceeding the Act 307 Type A or B cleanup criteria. Lead was detected in the surface soil from MP2SB6 (outside Site 2 boundaries) at a concentration of 31 mg/kg.

Groundwater Analytical Results

Groundwater occurs at depths between 1.5 and 2.4m (5 and 8 ft) bgs beneath Site 2 and flows northwesterly. Analytical results from the fourth round of groundwater sampling indicate only two compounds detected above Act 307 Type A or B cleanup criteria. PCE was detected down gradient of Building 7 at a concentration of 6.3 μg/l from MP2MW7 and arsenic (dissolved) was detected from MP2MW1 at a concentration of 7.1 μg/l.

Baseline Risk Assessment Results

Chemicals of potential concern at Site 2 were evaluated for the groundwater and soil pathways. Chemicals of potential concern were identified based on occurrence above MDNR Act 307 Type A or B cleanup criteria. Under Act 307, those chemicals occurring above Type A or B cleanup criteria require a site-specific risk assessment as part of Type C cleanup criteria. Chemicals of potential concern present in the groundwater include PCE and arsenic. No chemicals of potential concern were identified in the soil within the Site 2 boundaries.

Exposure scenarios evaluated include the present use of the land by the ANG, future use of the land by the ANG (including recreational activities), and future use of the land as a solely recreational facility (parks, camps, etc.). The most reasonably exposed populations include the current on-site employees and current recreational child; and the future on-site employee, future excavation worker, and future recreational child and adult. A worst-case scenario was evaluated for the adult by assuming the adult works on site at the facility and participates in weekend recreational activities.

The only potentially complete current exposure pathway at Site 2 is ingestion of contaminated groundwater from off-site bedrock wells, which is evaluated qualitatively since no data was collected on the bedrock aquifer. Complete future exposure pathways include future shallow aquifer groundwater exposure pathways (ingestion, dermal absorption, and inhalation of

VOCs) and deep aquifer exposure pathways (ingestion, dermal absorption, and inhalation of VOCs) through the use of production well PW2.

Carcinogenic and noncarcinogenic exposures were evaluated for all scenarios. Based on MDNR guidance, a reference level of 1×10^{-6} for carcinogens was used to evaluate the cancer risks. Cancer risks were summed for individual chemicals in a pathway and total pathway risks were then summed to provide an overall risk.

Future carcinogenic risks above 1×10^{-6} were calculated for the recreational child and on-site adult. Ingestion of shallow groundwater and ingestion of deep aquifer groundwater exceed the reference level by an order of magnitude for both receptors. Dermal contact with shallow groundwater exceeds the reference level, but is the same order of magnitude for the on-site adult only. Arsenic contributes 98-100% of the risk for the ingestion pathways. PCE contributes 68% of the risk from dermal contact. These results indicate that if Site 2 contaminants migrate to production well PW2 in the future, unacceptable cancer risks may occur through exposure to the drinking water supply.

The RfD was considered the reference level for noncarcinogens, based on EPA guidance. HQs are the ratio of the calculated exposure to the reference dose. Quotients greater than unity represent concern for noncarcinogenic effects. HQs were summed for all pathways to provide a pathway HI and all pathways were summed to provide a total exposure HI.

All HQs and pathway HIs are below 1 for both the future recreational child and on-site/recreational adult. Total exposure HIs are below 1 indicating a low potential for adverse noncarcinogenic health effects.

Uncertainties in the calculated carcinogenic and noncarcinogenic risks were evaluated. The major uncertainty is the assumption that current chemical concentrations will remain constant over the exposure time. This assumption overestimates the risk for the shallow and bedrock groundwater exposure pathways.

Environmental Assessment

A qualitative evaluation was performed of risks to the natural environment posed by chemicals of concern at Site 2. Chemicals above Act 307 Type A cleanup criteria for soils and above Act 307 GSI values in water were identified and potentially complete pathways evaluated.

No complete current exposure pathways were identified. Exposure pathways may become complete in the future; however, it is anticipated that should this occur the concentrations of chemicals of concern released will not adversely affect environmental receptors.

5.1.5 Site 3: Summary

Alpena County operated a maintenance garage at this site from the late 1940s to approximately 1973. The following summarizes the findings of the subsurface investigations conducted at Site 3:

Geology and Hydrogeology

Shallow aquifer materials beneath Site 3 are composed of quartz sand. The sand section is approximately 16.8 m (55 ft) thick. Below the sand a clay aquitard up to 3 m (10 ft) in thickness separating the shallow aquifer from the limestone bedrock aquifer.

Soil Analytical Results

Vinyl chloride (detected only in the 1987 SI) and SVOCs (PAHs) have been detected in site surface and subsurface soils in concentrations exceeding Act 307 Type B cleanup criteria. The occurrences of compounds exceeding Act 307 criteria appear to be of limited areal and vertical extent. Only one inorganic (selenium) from one soil sample collected during the SI was detected in concentrations exceeding Act 307 Type A cleanup criteria.

Groundwater Analytical Results

Groundwater occurs at depths between approximately 3.4 and 5.8 m (11 and 19 ft) bgs beneath Site 3 and flows northwesterly. Analytical results from the summer 1993 (Round IV) of groundwater sampling indicate no compounds were detected in concentrations exceeding Act 307 B cleanup criteria. In addition, no inorganics were detected in the filtered groundwater samples in concentrations exceeding the Act 307 Type A cleanup criteria.

Baseline Risk Assessment Results

Chemicals of potential concern at Site 3 were evaluated for the soils and groundwater pathways. Chemicals of potential concern were identified based on occurrence above MDNR Act 307 Type A or B clean up criteria. Under Act 307, those chemicals occurring above Type A or B clean up criteria require a site-specific risk assessment as part of Type C cleanup criteria. Chemicals of potential concern in the soil include benzo(a)anthracene, benzo (b) fluoranthene, benzo (k) fluoranthene, chrysene, dibenzofuran, indeno (1,2,3-c,d pyrene), and phenanthrene. No chemicals of concern were detected in the shallow aquifer groundwater.

Exposure scenarios evaluated include the present use of the land by the ANG (including recreational activities), future use of the land by the ANG, and future use of the land as a solely recreational facility. The most reasonably exposed populations include the current on-site employees and current recreational child, and the future on-site employee, future excavation worker, and future recreational child and adult.

No current complete exposure pathways were identified. Future complete exposure pathways include the excavation worker only. Pathways include subsurface soil (ingestion, dermal contact) and inhalation of fugitive dust.

Carcinogenic and noncarcinogenic exposures were evaluated for all scenarios. Based on MDNR guidance, a reference level of 1×10^{-6} for carcinogens was used to evaluate the cancer risks. Cancer risks were summed for individual chemicals in a pathway and total pathway risks were then summed to provide an overall risk.

Should excavation occur at Site 3, the evaluation of the exposure pathways indicate acceptable risk below 1×10^{-6}.

The RfD was considered the reference level for noncarcinogens, based on EPA guidance. HQs are the ratio of the calculated exposure to the reference dose. Quotients greater than unity represent concern for noncarcinogenic effects. HQs were summed for all exposure pathways to provide a pathway hazard index and all pathways were summed to provide a total exposure hazard index.

No HQs, pathway HIs, or total exposure HIs above 1 were calculated for the excavation worker. An HQ below 1 indicates a low potential for adverse noncarcinogenic effects.

Uncertainties in the carcinogenic and noncarcinogenic risk estimates were evaluated. The major uncertainty is the soil concentration used as the reasonable maximum exposure concentration throughout the site. In reality, the chemicals of concern detected in the soil are limited in areal extent and the risk to receptors is limited to a small portion of the site.

Environmental Assessment

A qualitative evaluation was performed of risks to the natural environment posed by chemicals of concern at Site 3. Chemicals above Act 307 Type A cleanup criteria for soils and above AWQC in water were identified and potentially complete pathways evaluated.

Chemicals of concern for the currently complete soils exposure pathway are PAHs, detected at a depth within the plant root zone. Potential receptors include terrestrial wildlife, birds, and plants. The chemical of concern which has a potential for future exposure through the surface water pathway is diethyl phthalate. Potential receptors include terrestrial wildlife, birds, and aquatic organisms at the sinkhole.

5.1.6 Site 4: Summary

Past fire training exercises have had an adverse impact on vadose zone soils at Site 4. The nature and extent of soil contamination was assessed during previous investigations performed at the site. These soils are included in a SRAP (Earth Technology, August 1993). The following summarizes the findings of the subsurface investigations conducted at Site 4.

Geology and Hydrogeology

Shallow aquifer materials beneath the site consist of approximately 10.7 to 12.2 m (35 to 40 ft) of medium- to coarse-grained, quartz sand. A thin (.6 to 1.5 m [2 to 5 ft] thick) sandy clay/clayey sand exists at the base of the shallow aquifer and separates this unit from the limestone bedrock.

Groundwater Analytical Results

Site 4 wells are well-located to monitor groundwater quality in the shallow aquifer. Through four rounds of groundwater sampling, no organic compounds have been detected in the wells which exceed the Act 307 Type B cleanup criteria. In addition, no inorganics exceeding the Act 307 Type A cleanup criteria have been quantified in the filtered groundwater samples collected from these wells.

Sediment and Surface Water Analytical Results

Sediment samples collected and analyzed from locations by the springs, and in the erosional gully leading to the sinkhole from Site 4, have contained only trace concentrations of organic compounds. TPH was detected in these samples in concentrations ranging from 25 to 51.9 mg/kg. Some of the sediment samples collected from the bottom of the sinkhole itself contain relatively high concentrations of TPH (25 to 1060 mg/kg). Surface water samples from the springs and sinkhole contain trace concentrations of a variety of organic compounds. Only copper and chromium were detected in the unfiltered surface water samples in concentrations exceeding the Act 307 Type B GSI criteria. Taken together these data indicate that there is evidence that fuel-related contaminants have at one time entered the sinkhole. The TPH detected in the bottom sediments may be the only remaining evidence of this contamination. The summer 1993 surface water and sediment sampling conducted from the springs shows that no organic compounds exceeding the Act 307 Type B GSI values are entering the sinkhole from the shallow aquifer.

Baseline Risk Assessment Results

Chemicals of potential concern at Site 4 were evaluated for the groundwater, surface water and sediment. Chemicals of potential concern were identified based on occurrence above MDNR Act 307 Type A or B clean up criteria. Under Act 307, those chemicals occurring above Type A or B cleanup criteria require a site-specific risk assessment as part of Type C clean up criteria. No chemicals of potential concern were detected in the groundwater. Chemicals of concern in the surface water include TCE and selenium. Additionally, all chemicals detected in the shallow aquifer throughout the facility were evaluated as chemicals of potential concern in the surface water (the sinkhole) at Site 4. These chemicals include carbon tetrachloride, PCE, arsenic, benzene, styrene, 1,2 dichloroethane, 1,4-dichlorobenzene, 2-methylnapthalene, and lead. Chemicals of concern in the sediment include selenium, methylene chloride, and 4-methylphenol.

Exposure scenarios evaluated include the present use of the land by the ANG (including recreational activities) future use of the land by the ANG, and future use of the land as a solely recreational facility. The most reasonably exposed populations include the current on-site employees and current recreational child, and the future on-site employee, future excavation worker, and future recreational child and adult.

No complete current exposure pathways were identified for Site 4. Future exposure pathways include ingestion and dermal contact with surface water at the sinkhole and incidental ingestion and dermal contact with sediments at the sinkhole.

Carcinogenic and noncarcinogenic exposures were evaluated for all scenarios. Based on MDNR guidance, a reference level of 1×10^{-6} for carcinogens was used to evaluate the cancer risks. Cancer risks were summed for individual chemicals in a pathway and total pathway risks were then summed to provide an overall risk.

Results indicate that no chemical-specific future cancer risks, pathway cancer risks, or total exposure cancer risk exists above the 1×10^{-6} acceptable level for surface water or sediment exposure pathways at the sinkhole for both the adult and child receptors.

The RfD was considered the reference level for noncarcinogens, based on EPA guidance. HQs are the ratio of the calculated exposure to the reference dose. Quotients greater than unity represent concern for noncarcinogenic effects. HQs were summed for all exposure pathways to provide a pathway HI and all pathways were summed to provide a total exposure HI.

Results indicate that chemical-specific HQs, pathway specific HIs and total exposure HIs are below 1, indicating low potential for adverse noncarcinogenic health effects.

Uncertainties in the calculations for carcinogenic and noncarcinogenic risks were evaluated. The major uncertainty is the reasonable maximum exposure concentration modeled for chemicals entering the sinkhole. The maximum concentration entering the sinkhole was used as the reasonable maximum exposure concentration. In reality the concentration of chemicals entering the sinkhole will vary considerably with time, and all chemicals will not reach the sinkhole at the same time.

Environmental Assessment

A qualitative evaluation was performed of risks to the natural environment posed by chemicals of concern at Site 4. Chemicals above Act 307 Type A cleanup criteria for soils and above Act 307 Type B GSI values in water were identified and potentially complete pathways evaluated.

Chemicals of concern for the currently complete surface water exposure pathways are chromium and copper, and for the sediments pathway arsenic, chromium, and selenium. Potential receptors include terrestrial wildlife, birds, plants, and aquatic organisms at the sinkhole. The chemicals of concern which have a potential for future exposure through the surface water pathway are cadmium, lead, nickel, and zinc and for the sediment pathway copper, cadmium, lead, nickel, and zinc. Potential receptors include terrestrial wildlife, birds, plants, and aquatic organisms.

5.1.7 Site 5: Summary

Past fire training exercises have likely led to the release of burned or partially burned fuels and/or solvents into the soils and groundwater at Site 5. An area of soil contamination has been identified and proposed for a focused feasibility study. Benzene and lead were detected in soils collected from this area at concentrations exceeding Act 307 Type A and B cleanup criteria. The following summarizes the findings of the subsurface investigations conducted at Site 5.

Geology and Hydrogeology

Approximately 6 m (20 ft) of soil, ranging in composition from clay to sandy gravel comprises the shallow aquifer beneath Site 5. Groundwater is encountered at a depth of 1.5 to 2.4 m (5 to 8 ft) bgs and flows southeasterly towards the sinkhole and westerly towards the river. The presence of a clay layer between the shallow aquifer and the limestone bedrock was not confirmed at all the locations sampled beneath Site 5.

Groundwater Analytical Results

Groundwater samples collected from the shallow aquifer contain organic compounds, particularly benzene, in concentrations exceeding the Act 307 Type B cleanup criteria. Data collected during the RI field investigations suggests that there is vertical movement of contaminants within the shallow aquifer beneath the site.

Baseline Risk Assessment Results

Chemicals of potential concern at Site 5 were evaluated for the surface water and shallow groundwater pathways for Site 5. Chemicals of potential concern were identified based on occurrence above MDNR Act 307 Type A or B cleanup criteria. Under Act 307, those chemicals occurring above Type A or B cleanup criteria require a site-specific risk assessment as part of Type C cleanup criteria. No chemicals of potential concern in the Lake Winyah surface water were identified. Chemicals of concern in the groundwater include styrene, benzene, 1,4-dichlorobenzene, and 1,2-dichloroethane. Chemicals of concern detected in the groundwater were also evaluated as future chemicals of potential concern in the surface water.

Exposure scenarios evaluated include the present use of the land by the ANG (including recreational activities), future use of the land by the ANG, and future use of the land as a solely recreational facility. The most reasonably exposed populations include the current on-site employees and current recreational child, and the future on-site employee, future excavation worker, and future recreational child and adult.

No current complete exposure pathways were identified at Site 5. Future exposure pathways involving the sinkhole were evaluated as part of Site 4. The only future complete exposure pathway considered is fish consumption from Lake Winyah.

Carcinogenic and noncarcinogenic exposures were evaluated for all scenarios. Based on MDNR guidance, a reference level of 1×10^{-6} for carcinogens was used to evaluate the cancer risks. Cancer risks were summed for individual chemicals in a pathway and total pathway risks were then summed to provide an overall risk.

No future risk above 1×10^{-6} was calculated for the recreational adult and child consuming fish from Lake Winyah.

The RfD was considered the reference level for noncarcinogens, based on EPA guidance. HQs are the ratio of the calculated exposure to the RfD. Quotients greater than unity represent concern for noncarcinogenic effects. HQs were summed for all exposure pathways to provide a pathway HI and all pathways were summed to provide a total exposure HI.

All current and HQs, and pathway HIs are below 1, indicating a low potential for adverse noncarcinogenic effects.

The major uncertainty in the evaluation of carcinogenic and noncarcinogenic risks is the concentrations modeled for chemicals entering Lake Winyah. Maximum concentrations entering the river were used as the reasonable maximum exposure concentration. In reality, the concentrations of the chemicals entering the sinkhole will vary considerably with time.

Environmental Assessment

A qualitative evaluation was performed of risks to the natural environment posed by chemicals of concern at Site 5. Chemicals above Act 307 Type A cleanup criteria for soils and above Act 307 Type B GSI values for water were identified and potentially complete pathways evaluated.

None of the exposure pathways at Site 5 are currently complete. Exposure pathways may become complete in the future however, it is anticipated that should they become complete the concentrations of chemicals of concern released will not adversely affect environmental receptors.

5.1.8 Sites 6 and 7: Summary

Past waste disposal practices and fire training exercises at Sites 6 and 7 have likely led to the release of waste POL and/or solvents into the soils and groundwater. The following summarizes the findings of the subsurface investigations conducted at Sites 6 and 7.

Geology and Hydrogeology

Native soils are generally sandy to a depth of approximately 9 feet bgs. An interbedded sand/sandy clay/clay unit approximately 10 feet thick separates the upper sand unit from a lower sand unit. The shallow aquifer water table is roughly coincident with the interbedded sand/sandy clay/clay unit and flows west towards the river and southeast towards the sinkhole from the site. Bedrock occurs beneath the sites in depths ranging from 8.2 to 12.8 m (27 to 42 ft) bgs. The presence of a clay layer between the shallow aquifer and the limestone bedrock was not confirmed.

Soil Analytical Results

Only lead, selenium, and zinc were detected in concentrations exceeding Act 307 Type A cleanup criteria from the soil samples collected and analyzed during the 1987 SI (Engineering-Science 1990).

Sediment Analytical Results

Sediment samples collected from the backwaters of Lake Winyah located adjacent to the landfill contain PAHs. These organic compounds have likely originated from the landfill and may be remnants of waste oils or construction debris such as asphalt pieces .

Groundwater Analytical Results

A groundwater divide exists beneath Sites 6 and 7. Groundwater quality is being monitored on either side of this divide. The results of the sampling and analysis indicate that although organic compounds and inorganics are being detected in the groundwater samples, only one well, LF6MW3 contains or has contained compounds exceeding the Act 307 Type A or B cleanup criteria. The analytical results suggest that the extent of contamination down gradient of LF6MW3 has been delineated. Fixed based analytical results compare poorly with

the two sets of field screening data collected from wells LF6MW5 and -MW8. The presence of clay-rich sediments in the shallowest portions of the saturated zone may be adsorbing organic compounds and prohibiting their partitioning into the groundwater.

Baseline Risk Assessment Results

Chemicals of potential concern were evaluated for the groundwater, surface water, sediment and soil pathways. Chemicals of potential concern were identified based on occurrence above MDNR Act 307 Type A or B clean up criteria. Under Act 307, those chemicals occurring above Type A or B cleanup criteria require a site specific risk assessment as part of Type C clean up criteria. Chemicals of potential concern in the groundwater are carbon tetrachloride. No current chemicals of concern were identified in the surface water. Carbon tetrachloride, present in the groundwater, was evaluated as a chemical of concern for future surface water pathways. No chemicals of concern were identified in the soils at Site 6/7. Chemicals of concern in the sediment include numerous PAHs, lead, selenium, and di-n-butyl phthalate.

Exposure scenarios evaluated include the present use of the land by the ANG (including recreational activities) future use of the land by the ANG, and future use of the land as a solely recreational facility. The most reasonably exposed populations include the current on-site employees and current recreational child and the future on-site employee, future excavation worker, and future recreational child and adult.

No current exposure pathways at Site 6/7 were identified. Future complete exposure pathways include Thunder Bay River surface water pathways (ingestion, dermal contact, and fish consumption) and backwater sediment pathways (dermal contact and ingestion).

Carcinogenic and noncarcinogenic exposures were evaluated for all scenarios. Based on MDNR guidance, a reference level of 1×10^{-6} for carcinogens was used to evaluate the cancer risks. Cancer risks were summed for individual chemicals in a pathway and total pathway risks were then summed to provide an overall risk.

The results indicate that exposure pathways involving the sediment in the backwater area of Lake Winyah (ingestion and dermal contact) exceed the 1×10^{-6} acceptable level for both the adult and child receptors. Dermal contact with sediment exceeds the reference level by an order of magnitude for both receptors. Benzo(a) pyrene contributes 76% of the risk. Ingestion of sediment exceeds the reference level, but is the same order of magnitude for the child receptor. These results indicate that an unacceptable risk may be present if recreational activities occur in the backwater area of Lake Winyah.

The was considered the reference level for noncarcinogens, based on EPA guidance. HQs are the ratio of the calculated exposure to the RfD. Quotients greater than unity represent concern for noncarcinogenic effects. HQs were summed for all exposure pathways to provide a pathway HI and all pathways were summed to provide a total exposure HI.

All chemical specific HQs, pathway HIs, and total exposure HIs are below 1 for both the adult and child receptors indicating a low potential for adverse noncarcinogenic health effects.

Uncertainties in the carcinogenic and noncarcinogenic risk estimates were evaluated. The largest uncertainty is the reasonable maximum exposure concentration of chemicals in the

backwater area of Lake Winyah. Only three samples were collected; all three were collected at the edge of the landfill, where landfill debris such as asphalt and construction debris may have been mixed with the sediments. The concentrations of PAHs detected in the sediments would likely be much lower further away from the ridge of the landfill.

Environmental Assessment

A qualitative evaluation was performed of risks to the natural environment posed by chemicals of concern at Site 6/7. Chemicals above Act 307 Type A cleanup criteria for soils and above Act 307 Type B GSI values in water were identified and potentially complete pathways evaluated.

Chemicals of concern for the currently completed surface water pathway are chromium, copper, lead, mercury, zinc, and for the sediment pathway lead, selenium, and PAHs. Potential receptors include terrestrial wildlife, birds, plants, and aquatic organisms backwater of the Lake Winyah backwater. The chemicals of concern which have a potential for future exposure through the sediment pathway are chromium, copper, lead, mercury, and zinc. Potential receptors include terrestrial wildlife, birds, plants, and aquatic organisms.

5.1.9 Site 8: Summary

RI sampling activities conducted at Site 8 were concentrated on the floor of the old Hangar 9 and the area surrounding Building 320. The following summarizes the major findings from the subsurface investigations performed at Site 8:

Geology and Hydrogeology

Sediments comprising the shallow aquifer beneath the site consist of a relatively uniform medium- to coarse-grained quartz sand containing minor gravel and/or gravel lenses overlying the limestone bedrock. The shallow aquifer sediments are approximately 60 feet thick beneath Site 8. An evaluation of the data collected during the field investigations shows that there is no well-defined clay layer separating the shallow aquifer from the bedrock.

Soil Analytical Results

No organic compounds were detected in site surface or subsurface soils in concentrations exceeding the Act 307 Type B cleanup criteria. Only two analytes, antimony and lead, were detected in the surface soil sample collected from HN8SB6 in concentrations exceeding the Act 307 Type A cleanup criteria.

Groundwater Analytical Results

Groundwater flow in the shallow aquifer beneath the site is directed to the northwest, towards the sinkhole. PCE has been detected in groundwater samples collected from HN8MW3 during the summer 1993 (Round IV) sampling event and in previous rounds of groundwater sampling in concentrations exceeding the Act 307 Type B criteria. No inorganics have been detected in the filtered groundwater samples exceeding the Act 307 Type A criteria during the four rounds of sampling.

Chemicals of potential concern were identified based on occurrence above MDNR Act 307 Type A or B clean up criteria. Under Act 307, those chemicals occurring above Type A or B cleanup criteria require a site specific risk assessment as part of Type C cleanup criteria.

Baseline Risk Assessment Results

Chemicals of potential concern at Site 8 were evaluated for soil and groundwater pathways. Chemicals of potential concern were identified based on occurrence above MDNR Act 307 Type A or B cleanup criteria. Under Act 307, those chemicals occurring above Type A or B cleanup criteria require a site-specific risk assessment as part of Type C cleanup criteria. PCE was determined to be a chemical of potential concern in the groundwater. Antimony and lead were determined to be chemicals of potential concern in the surface soil.

Exposure scenarios evaluated include the present use of the land by the ANG (including recreational activities), future use of the land by the ANG, and future use of the land as a solely recreational facility. The most reasonably exposed populations include the current on-site employees and current recreational child, and the future on-site employee, future excavation worker, and future recreational child and adult. A worst case scenario was evaluated for the adult by assuming the adult works at the facility and also takes part in weekend recreational activities.

Current complete exposure pathways are the soil pathways (ingestion and dermal contact with soils). The on-site adult is the only current receptor. Future exposure pathways include the above-listed soil pathways for the recreational child and future on-site/recreational adult. Additional future exposure pathways for the on-site/recreational adult and child include shallow aquifer groundwater pathways (drinking water ingestion, dermal contact, inhalation of VOCs during showering). If any future construction activities take place, then additional exposure soil pathways (ingestion, dermal contact, and inhalation of fugitive dust) become complete for the excavation worker.

Carcinogenic and noncarcinogenic exposures were evaluated for all scenarios. Based on MDNR guidance, a reference level of 1×10^{-6} for carcinogens was used to evaluated the cancer risks. Cancer risks were summed for individual chemicals in a pathway, and total pathway risks were then summed to provide an overall risk.

No SFs were available for antimony and lead; consequently, no cancer estimate was calculated for the soil pathway for the current adult, future adult, and excavation worker. The results for the future land-use scenarios indicate a cancer risk below 1×10^{-6} for the recreational child, and on-site/recreational adult indicating acceptable risk for all exposure pathways.

The results for the future land-use scenarios indicate a cancer risk below 1×10^{-6} for the recreational child and on-site/recreational adult, indicating acceptable risk for all pathways.

The RfD was considered the reference level for noncarcinogens, based on EPA guidance. HQs are the ratio of the calculated exposure to the RfD. Quotients greater than unity represent concern for noncarcinogenic effects.

HQs were summed for all exposure pathways to provide a pathway HI, and all pathways were summed to provide a total exposure HI.

No current HQs or pathway HIs are above the reference level of 1, indicating low potential for adverse noncarcinogenic effects. No future HQs or pathway HIs are above the reference level of 1. Total exposure HIs are below 1 for all receptors, indicating low potential for adverse noncarcinogenic effects.

Uncertainties in the carcinogenic and noncarcinogenic risk estimates were evaluated. One of the major uncertainties is the lack of toxicity values for lead. The total risk without considering lead is underestimated.

Environmental Assessment

A qualitative evaluation was performed of risks to the natural environment posed by chemicals of concern at Site 8. Chemicals above ACT 307 Type A cleanup criteria for soils and above Act 307 Type B GSI values in water were identified, and potentially complete pathways evaluated.

Chemicals of concern for the currently complete soils exposure pathway are antimony and lead. Potential receptors include terrestrial wildlife, birds, and plants. The chemical of concern which has a potential for future exposure at the sinkhole through the surface water and sediment pathway is diethyl phthalate. Potential receptors include terrestrial wildlife, birds, plants, and aquatic organisms.

5.1.10 Site 9: Summary

RI activities conducted at Site 9 concentrated on the area surrounding the AGE shop. The following summarizes the findings of the subsurface investigations performed at Site 9:

Geology and Hydrogeology

Sediments comprising the shallow aquifer beneath the site consist of a relatively uniform, medium- to coarse-grained, quartz sand overlying the limestone bedrock. The shallow aquifer is approximately 60 ft thick beneath Site 9. An evaluation of the data collected during the field investigations suggests there is no well-defined clay layer separating the shallow aquifer from the bedrock.

Soil Analytical Results

Analytical results show the surface and subsurface soils are relatively free of chemicals of concern exceeding Act 307 Type A or B cleanup criteria. Only PCE, detected during the 1987 SI at 27 μg/kg from one subsurface soil sample was present in concentrations exceeding Act 307 Type B cleanup criteria.

Groundwater Analytical Results

Groundwater flow in the shallow aquifer beneath the site is to the north towards the sinkhole. PCE has been detected in the summer 1993 and in previous rounds of groundwater sampling in concentrations exceeding the Act 307 Type B cleanup criteria. In addition, fuel-related groundwater contamination was detected in samples collected from RT9MW6 during the RI sampling and analysis. Benzene, 2-methylnapthalene, lead, and 1,4-DCB were detected in groundwater samples collected from RT9MW6 in concentrations exceeding the Act 307 Type A or B cleanup criteria. These compounds have likely originated from minor spills which have occurred during routine fuel handling and/or maintenance activities conducted at the AGE shop (Building 417). The on-site GC screening data and the fixed based analytical data suggest the extent of groundwater contamination existing at Site 9 has been delineated.

Chemicals of potential concern were identified based on occurrence above MDNR Act 307 Type A or B cleanup criteria. Under Act 307, those chemicals occurring above Type A or B cleanup criteria require a site-specific risk assessment as part of Type C cleanup criteria.

Baseline Risk Assessment Results

Chemicals of potential concern were evaluated for Site 9 soil and groundwater pathways. Chemicals of potential concern were identified based on occurrence above MDNR Act 307 Type A or B cleanup criteria. Under Act 307, those chemicals occurring above Type A or B cleanup criteria require a site-specific risk assessment as part of Type C cleanup criteria. Chemicals of concern present in the groundwater are PCE, 2-methylnapthalene, 1,4-dichlorobenzene, benzene, and lead. No chemicals of concern were detected in the soils.

Exposure scenarios evaluated include the present use of the land by the ANG (including recreational activities), future use of the land by the ANG, and future use of the land as a solely recreational facility. The most reasonably exposed populations include the current on-site employees and current recreational child, and the future on-site employee, future excavation worker, and future recreational child and adult.

No complete current exposure pathways were identified at Site 9. Future complete exposure pathways are those related to groundwater (ingestion, dermal contact, and inhalation of VOCs).

Carcinogenic and noncarcinogenic exposures were evaluated for all scenarios. Based on MDNR guidance, a reference level of 1×10^{-6} for carcinogens was used to evaluate the cancer risks. Cancer risks were summed for individual chemicals in a pathway and total pathway risks were then summed to provide an overall risk.

The results indicate that a total future exposure cancer risk equal to, but not exceeding, exists for the recreational child. No individual exposure pathways exhibit cancer risks above 1×10^{-6}. The total future exposure cancer risk for the on-site/recreational adult exceeds 1×10^{-6}, indicating an unacceptable risk level. The cancer risk for groundwater ingestion exceed 1×10^{-6}, but is the same order of magnatude with 1,4 dichlorobenzene contributing 50% of the risk.

The RfD was considered the reference level for noncarcinogens, based on EPA guidance. HQs are the ratio of the calculated exposure to the RfD. Quotients greater than unity represent concern for noncarcinogenic effects. HQs were summed for all exposure pathways to provide a pathway HI and all pathways were summed to provide a total exposure HI.

The results indicate chemical-specific HQs, total pathway HIs, and total exposure HIs are all below 1 for both the recreational child and on-site/recreational adult. The results indicate a low potential for adverse noncarcinogenic effects.

Uncertainties in the carcinogenic and noncarcinogenic risk estimates were evaluated. One of the major uncertainties is the assumption that the exposure concentration remains the same throughout the exposure period. In reality the exposure concentration will vary with time. This assumption likely overestimates the risk.

Environmental Assessment

A qualitative evaluation was performed of risks to the natural environment posed by chemicals of concern at Site 9. Chemicals above Act 307 Type A cleanup criteria for soils and above Act 307 Type B GSI values in water were identified and potentially complete pathway evaluated.

Currently, no exposure pathways are complete at Site 9. Potential future exposure pathways which may release 1, 2-dimethyl/benzene, 1, 3-dimethylbenzene, and 1, 4-dimethylbenzene are surface water and sediments. Potential receptors include wildlife, birds, plants, and aquatic organisms.

5.1.11 Production Wells

Six production wells, numbered PW1 through PW6 exist on the facility. Well PW1 has been the water supply well for the facility since 1942 and is completed in the limestone aquifer. Average daily water use for the facility is approximately 50,000 gpd. Production wells PW2 (completed in both the shallow and limestone aquifers) and PW3 (completed within the shallow aquifer) are no longer in service. However, PW2 is the alternate water supply well for the facility and would be used if PW1 was unable to be used. Production wells PW4, (completed in the limestone aquifer), PW5 (completed in the Bell Shale bedrock aquifer), and PW6 (completed in the shallow aquifer) are still in use, but supply only a small quantity of water to isolated areas of the facility.

Wells PW4, PW5, and PW6 were sampled only during the initial two rounds of groundwater sampling conducted during the SI (Engineering-Science 1990). Bis (2-Ethylhexyl) phthalate was detected during the November 1987 (Round I) sampling at a concentration exceeding the Act 307 Type B cleanup criteria in samples collected from PW4. No other organic compounds were detected in concentrations exceeding the Act 307 Type B cleanup criteria in the samples collected from these wells. Four rounds of groundwater sampling have been conducted from wells PW1, PW2, and PW3. Organic compounds detected during the four rounds of sampling exceeding the Act 307 Type B cleanup criteria include bis (2-Ethylhexyl) phthalate and carbon tetrachloride. Carbon tetrachloride was detected during the October 1991 (Round III) and summer 1993 (Round IV) sampling events from PW3 at concentrations of 1.5 and 1.2 ug/l,

respectively. Bis (2-Ethylhexyl) phthalate was detected in samples collected from PW1 during the November 1987 (Round I) groundwater sampling event. Act 307 Type A cleanup criteria (local background concentrations) have not been determined for the bedrock aquifer. Therefore, a comparison of the inorganic concentrations detected in the samples collected from the bedrock aquifers (wells PW1, PW2, PW4, and PW5) to the Act 307 Type A cleanup criteria could not be made. Groundwater samples obtained from wells PW3 (all four rounds) and PW6 (the initial two rounds) did not contain inorganics in concentrations exceeding the Act 307 Type A cleanup criteria.

5.2 CONCLUSIONS AND RECOMMENDATIONS

Conclusions and recommendations have been prepared for each site based on the results of the field investigations and the baseline risk assessment. Facility wide conclusions and recommendations have also been included.

5.2.1 Facility-Wide Conclusions and Recommendations

RI field sampling activities were focused on defining the nature and extent of contamination within the soils, sediment, surface water, and groundwater contained within the shallow aquifer beneath the Alpena CRTC for IRP Sites 1 through 9 and groundwater coming from facility water supply wells PW1, PW2, and PW3. Additionally, a groundwater model was created and used to estimate future contaminant concentrations originating in the shallow aquifer and being transported to the sinkhole, the production wells, and the surface water bodies bordering the facility. These data were used to produce an ecological and human health risk assessment for current and future exposure to the previously listed media. Data were collected regarding the presence and extent of the clay layer separating the shallow aquifer from the limestone aquifer and qualitative evaluation was made regarding the potential for a health risk from contaminant migration into the limestone aquifer.

5.2.2 Site – 1 POL Storage Area

Past fuel handling activities performed at the old POL Storage Area have led to the release of fuels into the subsurface environment. Soil and groundwater analytical results suggest the nature and extent of contaminated media have been delineated. No unacceptable carcinogenic risks were calculated for current or future exposure to Site 1 soils. An analysis of the available soils analytical data shows only one area of the site poses an unacceptable non-carcinogenic risk. This area of soil contamination is centered around boring S1SB1 and corresponds to the location of a pre-existing, aboveground fuel storage tank. HQs above 1 were calculated for inhalation of VOCs contained in the soil for excavation workers. It is recommended that a focused feasibility study be performed for this area of Site 1. Additional soil borings are recommended to better define the limits of contamination. Results from this sampling should be evaluated, and if necessary additional areas included in the focused feasibility study.

There are no current complete pathways for exposure to the shallow groundwater. Evaluation of the future complete pathways for groundwater exposure indicates a potential carcinogenic

risk, equal to but not exceeding the 1×10^{-6} acceptable risk level, from the domestic use of water from production well PW3. Well PW3 is not used as a water supply well for the facility. It is recommended to abandon PW3 to eliminate the potential future use of this well. If this exposure pathway is eliminated, the remaining groundwater exposure pathways evaluated during the risk assessment indicate acceptable levels of risk; therefore, it may not be necessary to initiate remedial actions to treat the presence of organic compounds (i.e. benzene) present in the Site 1 groundwater samples above Act 307 Type B cleanup criteria.

Groundwater contained in the shallow aquifer also discharges into the Thunder Bay River. Results obtained from the ecological risk assessment indicate future detrimental affects on the aquatic population in the river from exposure to metals (particularly chromium) contained in the shallow groundwater. The ecological risk exposure estimates were based on the total (unfiltered) groundwater analytical results, which are significantly higher than the corresponding dissolved (filtered) results. All unfiltered groundwater samples collected from Site 1 wells were described as turbid, possibly because the wells were installed, developed, and sampled within a relatively short period of time (approximately three weeks). It is recommended to redevelop and resample these wells to ensure that representative total metals concentrations for the shallow aquifer were used in the risk evaluation. Additionally, chromium concentrations should be reported as Cr^{+6} and Cr^{+3}, rather than total chromium. If resampling indicates levels of metals are within acceptable limits, then remedial actions would not be necessary to treat metals in the groundwater at the point of discharge to the Thunder Bay River.

The presence of the intermediate-depth clay layer and the analytical results obtained from the S1MW6/S1MW14 well pair suggest that groundwater quality in the limestone aquifer beneath Site 1 has probably not been adversely affected by the VOCs detected in the shallow aquifer beneath Site 1. Future affects could be evaluated by periodic sampling and trend analysis of VOC concentrations from groundwater contained within well S1MW14.

5.2.3 Site 2 – Motor Pool Area

Surface and subsurface soil samples were collected from the most probable sources of environmental contamination existing at Site 2, including the floor drain in front of the vehicle maintenance shop, and the facility vehicle refueling USTs. No chemicals of concern were identified from the analytical results obtained from these soil samples. One detection of lead in a concentration exceeding the Act 307 Type A cleanup criteria was quantified in a surface soil sample located outside of the site boundaries. These data were not included in the risk assessment. Based on the soils analytical data evaluated and included in this RI Report, no further remedial actions are recommended for the soils within Site 2.

Groundwater analytical results suggest the extent of groundwater contamination in the shallow aquifer beneath Site 2 has been delineated. Future unacceptable carcinogenic risks for adults and children would result from the use of groundwater from the shallow aquifer or from PW2. Because only future use of the groundwater beneath Site 2 results in unacceptable risks, it is recommended that the MIANG institute controls to prohibit the use of shallow groundwater from beneath the area. Additionally, future unacceptable carcinogenic risks may occur from use of groundwater from the aquifer through migration of Site 2 contaminants to production well PW2, which is screened in the shallow and limestone

aquifers. It is recommended that PW2 be abandoned to eliminate this future risk to the limestone bedrock aquifer. If PW2 is abandoned, then there appears to be limited potential for interaction of the two aquifers, based on the presence of a clay layer between the shallow and bedrock aquifers.

5.2.4 Site 3 – Former Site of County Garage

Surface and subsurface soil samples were collected during the RI from data gaps identified during an evaluation of the SI analytical results. The RI soils data were used in a quantitative risk assessment. Unacceptable carcinogenic risks due to exposure to PAHs were calculated for current and future on-site personnel and future child populations under the current and future land-use scenarios. Additionally, if construction activities were to be completed for this area of Site 3, excavation workers would be exposed to unacceptable carcinogenic risks from these same soils. The soils containing the PAHs are centered around CG3SB13. It is recommended that a removal action be performed for this area of Site 3.

No chemicals were identified above the Act 307 Type B cleanup criteria in the groundwater. However, VOCs were detected in the newly installed wells placed in the area where the wells were abandoned in 1992. A hydrocarbon sheen was noted at the time of the well abandonment. It is recommended that the Site 3 wells be resampled to confirm the concentrations detected in the newly installed wells. It is also recommended that piezometer CG3PZ2, also located in the abandoned well area, be sampled. This piezometer was constructed such that it could be developed and sampled if necessary.

Based on the presence of the observed clay layer separating the shallow aquifer from the limestone aquifer, groundwater contained within each aquifer should have a very limited potential for interaction. The groundwater contained within the shallow aquifer is considered to have a low probability of adversely affecting groundwater quality in the limestone aquifer beneath Site 3.

5.2.5 Site 4 – Third Fire Training Area

Past fire training exercises have led to the release of burned or partially burned fuels to the subsurface environment beneath Site 4. An area of soil contamination has been identified at Site 4 and has been proposed for a source removal action (The Earth Technology Corporation, June 1994).

Trace concentrations of organic compounds were detected in the sediment and surface water samples from locations by the springs leading to the sinkhole. Trace concentrations of organics were detected in the surface water of the sinkhole. No current complete pathways exist for human exposure to sediment or surface water at the sinkhole. If future recreational activities occur at the sinkhole, no unacceptable health risks are indicated by the risk assessment.

The ecological assessment indicates a current and future potential risk to aquatic receptors from metals present in the surface water and sediments at the sinkhole. This assessment was qualitative for the sediments. The metals are present in the surface water above Act 307 GSI values. Total metals were used in the surface water evaluation which may overestimate the

concentration due to the difficulty of sampling shallow springs. Total metals were detected in only one spring sample SW003. It is recommended that the springs be resampled to verify the concentrations detected. Additionally, chromium should be reported as Cr^{+6} and Cr^{+3}.

No chemicals of concern were selected from an evaluation of the Site 4 summer 1993 (Round IV) groundwater analytical results. Based on these analytical results, no remedial actions are recommended for the groundwater contained within the shallow aquifer beneath Site 4.

Because to date, the groundwater analytical results show no measurable adverse impact on groundwater quality within the shallow aquifer beneath Site 4, it is unlikely that groundwater quality within the limestone aquifer has been adversely affected. Future affects could only be evaluated by periodic sampling and trend analysis of groundwater analyses from the Site 4 monitoring wells.

5.2.6 Site 5 – Second Fire Training Area

Past fire training exercises have led to the release of burned or partially burned fuels and/or solvents to the subsurface environment beneath Site 5. An area of soil contamination has been identified at the site and has been proposed for a focused feasibility study.

No current complete pathways are present at Site 5. The only future pathway is ingestion of contaminated fish from Lake Winyah. The shallow aquifer beneath Site 5 is considered too shallow to support a domestic well; therefore, no groundwater pathways were considered. No future unacceptable risk exists for ingestion of fish from Lake Winyah. No ecological risks were identified at Site 5.

Groundwater analytical results (both onsite GC analysis and fixed based laboratory) suggest that contaminant migration within the shallow aquifer contains a component of downward movement. In addition, gravel lenses were observed above the limestone bedrock during the drilling of wells SF5MW5 and SF5MW6. One round of the historic groundwater elevation measurements (Round III: Earth Technology Corporation, July 1992) show groundwater flow beneath the site directed towards the river, rather than the sinkhole. These data suggests that groundwater flow and contaminant migration are complex beneath Site 5, and that the extent of shallow groundwater contamination beneath the site may not be fully delineated. At a minimum it is recommended to install wells to monitor the lower zone of the shallow aquifer at locations SF5MW5 and SF5MW6. A focused feasibility study is also recommended for the shallow groundwater at Site 5.

5.2.7 Sites 6 and 7 – Former Landfill and First Fire Training Area

Past waste disposal practices and fire training exercises at Sites 6 and 7 have probably led to the release of waste POL and/or solvents into the soils and groundwater beneath the site.

The analytical results obtained during the SI for the surface and subsurface soils at Sites 6 and 7 were not used to perform a risk assessment, but were evaluated with respect to the chemical-specific Act 307 Type and B cleanup criteria. Only lead, selenium, and zinc were

detected in site soils above the Act 307 Type A cleanup criteria. The few occurrences of these compounds exceeding the Act 307 Type A cleanup criteria are considered outliers and are not associated with past fire training or waste disposal activities. Based on these analytical results, no further remedial actions should be taken for the soils beneath Sites 6 and 7.

Groundwater analytical results suggest the nature and extent of groundwater contamination in the shallow aquifer beneath Sites 6 and 7 has been delineated. No current complete groundwater exposure pathways were identified for the site. The shallow aquifer beneath the site was assumed to be too thin to support a domestic well; therefore, no future groundwater pathways were evaluated.

No chemicals of concern were identified for the current surface water pathway. Future chemicals of concern are those chemicals present in the groundwater. No unacceptable human health risk was identified for the future surface water pathways for the adult or child receptors. Potential ecological risks from metals were identified based on groundwater results from the edge of the landfill (LF6MW9). Total metals were used in the evaluation and it is likely that these levels are elevated as a result of sampling a newly installed well. It is recommended that the wells at Site 6/7 be redeveloped and resampled to verify the concentration of metals present in the groundwater. Chromium should be reported as Cr^{+3} and Cr^{+6}.

Chemicals of concern were identified in the sediments of the backwater area of Lake Winyah. This area is not currently used; therefore, no current complete pathways exist. If receptors are exposed in the future an unacceptable carcinogenic risk may exist. Potential current ecological risks were also identified. The three samples from the backwater area were obtained from the edge of the landfill and were reported to contain asphalt-like particles. It is likely that the PAHs in the sediment will decrease further away from the landfill. Because this is an ecologically sensitive area, it is recommended that additional sediment samples be obtained to further characterize the backwater area.

VOCs exceeding the Act 307 Type B cleanup criteria occur in the lower portion of the shallow aquifer (based on the results from LF6MW3) and no clay layer was observed beneath the site that might prohibit the migration of contaminated groundwater from entering the limestone aquifer. These data suggest that a potential exists that groundwater quality in the lower aquifer may be adversely affected by contaminated groundwater contained within the shallow aquifer.

5.2.8 Site 8 – Former Site of Hangar 9

RI soil and groundwater sampling activities completed for the site were concentrated in the floor of the old Hangar 9 and the area surrounding Building 320. Soil and groundwater analytical results suggest the nature and extent of contaminated media have been delineated. The Site 8 risk assessment determined that no current or future populations were exposed to unacceptable carcinogenic or non-carcinogenic risks through exposure to site soils or groundwater. Based on the soil and groundwater analytical data evaluated during this RI report, no further remedial actions are recommended for the soils at and the groundwater contained within the shallow aquifer beneath Site 8.

A relatively small vertical gradient exists between the upper and lower zones of the shallow aquifer beneath the site. Groundwater contained in the shallow aquifer appears to have little tendency to flow vertically down through the shallow aquifer toward the limestone aquifer. These data suggest there is a relatively low potential for groundwater contained in the shallow aquifer to be migrating vertically down into the limestone aquifer and affecting groundwater quality in the limestone aquifer.

5.2.9 Site 9 – Radar Tower Site

Building 417, the AGE Shop is contained within the boundaries of Site 9. Field sampling activities completed during this RI and previous IRP studies for Site 9 have concentrated on the AGE Shop. Soil samples were selected from the most probable source areas (based on the SOV survey) within Site 9. No chemicals of concern (i.e. compounds exceeding the Act 307 Type A or B cleanup criteria) were determined from an evaluation of the RI analytical soil results. Based on this evaluation, it is recommended that no further remedial actions be completed for the Site 9 soils.

Groundwater analytical results suggest the nature and extent of groundwater contamination in the shallow aquifer beneath Site 9 has been delineated. No current complete groundwater exposure pathways were identified for Site 9. Future shallow aquifer groundwater pathways were evaluated. Future acceptable non-carcinogenic risks were quantified for all receptors potentially using the shallow groundwater. Future unacceptable carcinogenic risks were calculated for recreational children and adults using site groundwater for domestic-type uses and for adult employees potentially using the groundwater beneath Site 9. Because only future use of the groundwater beneath the site results in unacceptable risks, it is recommended that the MIANG institute controls to prohibit the use of shallow groundwater from beneath the area.

The analytical data suggest that contaminants are not migrating vertically within the water column beneath the site. Because no clay layer was observed separating the shallow aquifer from the limestone aquifer beneath Site 9, there is no barrier that could prevent groundwater from migrating into the limestone aquifer. Based on these data, there exists a medium to high potential that the shallow aquifer could be adversely affected by contaminated groundwater occurring in the shallow aquifer. It is recommended that the shallow/deep well pair be routinely monitored to detect any migration toward the limestone aquifer.

5.2.10 Production Wells

Six production wells exist on the facility. PW4, PW5, and PW6 are up gradient of the sites and were only sampled during the 1987 initial round of sampling. No compounds were detected above the Act 307 Type A or B cleanup criteria. PW1, PW2, and PW3 have been sampled for four rounds. No organic compounds were detected in the fourth round at concentrations exceeding the Act 307 Type B cleanup criteria in PW1 or PW2. Carbon tetrachloride above Act 307 Type B cleanup criteria was detected in PW3. No inorganic analytes above Act 307 Type A cleanup criteria were detected in PW3. PW1 and PW2 are screened in the limestone aquifer. There is insufficient data available from the facility to quantify local background chemistry for the limestone aquifer.

It is recommended that PW2 and PW3 be abandoned. PW2 is screened in both aquifers and the method of construction may provide a conduit for contaminant migration between the two aquifers. PW3 is screened in the shallow aquifer. VOCs have been detected in this well at concentrations which may pose an unacceptable health risk.

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